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NOW IS THE TIME

IN the nine months from October, 1937, to June, 1938, what we have politely called a recession resulted in the most drastic decline ever recorded in American business. Now it is increasingly evident that we are already well advanced on the reverse scale, with the stage set for rapid recovery. Never before has government spending and lending been at such a high rate as in recent months. A housing boom long overdue seems at last to be getting under way. Automobile manufacturers, in striking contrast with their predictions of a year ago, have hoisted their estimates from a 3,000,000 to a 4,000,000 car year for 1939. Steel, glass, rubber, paint industries become more optimistic. All this adds up, so the economist tells us, to an immediate opportunity that business cannot afford to overlook.

Many chemical process industries have been quick to sense this change in business sentiment. Plans for new plants have been announced within the month which in the aggregate will exceed $30,000,000. *Chem. & Met.'s* new index of chemical consumption turned upward in July and has risen steadily ever since. This means but one thing—an increasing scale of operations.

If profits are to be made at present price levels, costs of operation and of new plant construction must come down. Processes and equipment must be modernized to take full advantage of recent advances in technology. New and better materials are now becoming available in greater number and at lower prices. In the two-year interval since *Chem. & Met.'s* Seventh Materials of Construction Issue, the number of products has increased from approximately 650 to 800. The gain is actually more than the total number of such materials listed in our 1929 survey. And there has been corresponding progress in improved composition and properties of many of the alloys and non-metallic materials available for use in process equipment and plant construction.

This eighth issue in our series should serve a timely and useful purpose. Its text presents the fundamental considerations involved in the selection and utilization of the various classes of materials. Its data sheets (beginning on page 629) bring up to date the basic information on composition, properties, trade names and manufacturers. In effect, it is a complete mobilization of available information. Now is the time to put it to work.

ALLOY STEEL DEVELOPMENTS

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THE DEVELOPMENT OF ALLOY STEELS by the metallurgical industry is keeping pace with and is conditioned by the development of new products in the process industries. Many types of alloy steels have been produced to meet the demand for better resistance to corrosion, abrasion and oxidation. It is obvious that the chemical engineer responsible for deciding which of these materials is to be used for equipping a new process must be armed with a large amount of comparative metallurgical, engineering and fabrication test data.

Let us consider a method for the selection of alloy steels that is working successfully in the industry.

The managements of a number of concerns in the process industries, the nature of whose business is entirely chemical, recognizing that their progress is dependent on the advancement of alloy steels, have established separate research and development departments in metallurgy. The function of these departments aside from the evaluation of commercial alloys, improvement and development of new alloys for meeting the demands of highly specialized processes, and the investigation of fabrication processes, is to collect and correlate metallurgical data with the chemical, engineering, design and fabrication factors for the purpose of aiding in the selection of the most suitable alloy steels for process equipment used in the plant.

Paper mill blowpit piping fabricated of Cb-bearing stainless steel

Early in the process development the research chemist acquaints the metallurgist with all angles of his problem. The metallurgist, familiar with the details of the problem and the general advantages and fabrication limitations of alloys, selects a group of the most promising alloys and conducts preliminary corrosion tests in the process reactions while they are still being made in glass apparatus. These or similar tests duplicating process conditions determine the relative corrosion resistance and the catalytic effect of the metal on the product. It is sometimes necessary to reject an alloy because some alloying element has an adverse effect on the yield of the product. Based on the results of these preliminary tests, the pilot plant is constructed and during the same period in which the development engineer is stepping up the process from the laboratory to semi-plant scale operations, the metallurgist and design engineer are testing the alloys as fabricated equipment or as additional test samples under actual service conditions.

It is realized that this system, the cooperative efforts of specialists, is the ideal method for selecting an alloy steel construction material for equipping a plant, but that many units in the process industries do not have access to these facilities. However, in the many instances where the plant engineer alone is responsible for the construction of process equipment, there is no reason why he cannot adopt the same testing procedure, and, without the necessity of disclosing details of the process, cooperate with the producers and fabricators of alloy steels. In any event, alloy steel producers and fabricators who have a vast fund of information based on both laboratory tests and experience, should be brought into the picture before the final specifications are made. Considerable authentic data are available in the literature showing the results of tests of the various commercial alloys under conditions similar to applications in question. These can only be used as an indicator or as a guide in the selection of a construction material for testing. Because of the multiplicity of variations and complications encountered in every process, the only entirely safe method of selecting materials for process equipment is to test the alloy steel under exact process conditions.

With this end in view, it is the object of this article to assist the chemical engineer in selecting alloy steels for his specialized requirements by citing examples and discussing the function of alloying elements, particularly as they affect fabrication.

Chromium, because of its inherent characteristic to resist corrosion, oxidation and abrasion, and its ability to impart these properties as well as strength and hardness to steel even at elevated temperatures is the most effective element used in alloys for process equipment. For this reason the alloy steels, for the most part, are grouped in this article according to their chromium content.

Mild Corrosion up to 1100 Deg. F.

The straight chromium steels containing from 0.50 to 10 per cent chromium with and without additional modifying elements are used principally to obtain greater strength, resistance to shock, and resistance to mild or moderately severe conditions of corrosion up to temperatures at which ordinary carbon steel begins to scale rapidly (900 to 1100 deg. F.). The resistance to corrosion and oxidation increases as the chromium content is raised. This class of alloy steels is, in general, air hardening but if the carbon is sufficiently low (about 0.14 per cent) in the very low chromium range (approx. 1.00 per cent), the steels are not air hardening. Such chromium to carbon ratio is found among the low alloy, high tensile, structural steels that are supplied in a number of compositions by several steel companies. These steels containing from 0.10 to 0.30 per cent carbon depend on a major element, chromium, nickel or manganese, for strength, and upon modifying elements, silicon, molybdenum or vanadium, for emphasizing the effect of the major element and improving ductil-

ity, and upon phosphorus and copper for corrosion resistance. They are used to replace carbon steel in applications requiring high strength, resistance to shock, and resistance to mild corrosion. Economies are effected by taking advantage of the strength and corrosion resistance to design lighter equipment.

Steels containing 1.50 to 2.75 per cent chromium modified with molybdenum, vanadium, and nickel are used to resist the decarburization of hydrogen at high temperatures and pressures in the synthesis of ammonia and the hydrogenation of coal and oil. The addition of chromium to steel progressively improves the resistance to hydrogen attack. In a paper presented before the British Institute of Metals ("The Effect on Various Steels of Hydrogen at High Pressures and Temperatures," Journal of the Iron & Steel Institute, Vol. 58, Part 2, 1933), N. P. Inglis and W. Andrews show that a mild carbon steel is attacked by hydrogen under a pressure of 3,750 lb. per sq. in. when the temperature exceeds 390 deg. F. A 3 per cent chromium steel at the same pressure will be resistant to the attack of hydrogen at a temperature of 750 deg. F. while a 6 per cent chromium steel is resistant to a temperature of at least 930 deg. F.

Alloy steels containing from 2 to 10 per cent chromium with additions of molybdenum, tungsten, silicon, aluminum, columbium, or titanium are being used particularly for tubing to resist moderate corrosive conditions at temperatures up to 1100 deg. F.

The most important in this range is the 4 to 6 per cent chromium, 0.5 per cent molybdenum, 0.10 per cent carbon, which is used extensively in the oil industry for cracking tubes, hot oil and vapor lines, oil preheaters, oil and vapor heat exchangers, and still tubes, and as superheater tubes in high pressure steam boilers operating at pressures up to 750 lb. per sq. in. and temperatures up to 1100 deg. F. The addition of molybdenum improves strength at high temperatures and also prevents the temper brittleness to which the plain chromium steels are subject when exposed to temperatures of 900 deg. F. and cooled to atmospheric temperature. Tungsten is likewise effective in increasing strength at high temperatures. Columbium and titanium prevent air hardening, and increase the resistance to oxidation and corrosion because they have a greater affinity for carbon than chromium has and thus combine with the carbon, permitting the retention of more chromium in the alloy matrix. Columbium also increases the impact strength and toughness. The use of columbium or titanium bearing composition has greatly facilitated the design and fabrication of equipment made from this steel by eliminating the necessity for annealing after welding.

Moderate Corrosion up to 1300 Deg. F.

The 12 to 14 per cent chromium alloy steels with and without molybdenum or tungsten are used for fairly corrosive conditions up to temperatures of 1250 to 1300 deg. F. The grade containing a maximum of 0.12 per cent carbon can be heat treated to give a wide variety of physical properties. Because of its combination of high strength and resistance to erosion and cavitation it is a particularly suitable material for turbine blades and is commonly known as turbine steel. It has a number of applications such as in valve parts and shafting. In the annealed condition this grade is suitable for border line applications between moderately corrosive and severely corrosive conditions. One large use is linings for columns and pressure vessels of large cross section in the oil industry. The high chromium steel liners are welded to the plain carbon steel either by hot rolling or spot welding.

The 0.30 to 0.40 per cent carbon, 12 to 14 per cent chromium, or cutlery grade responds to heat treatment to give a wide variety of physical properties. It may be hardened and is used where a combination of hardness and corrosion and wear resistance is required such as for knives, scrapers, and dies. These steels can be fabricated only in the annealed condition; after hardening the fabrication is limited to grinding and brazing.

All the air hardening steels containing up to 14 per cent chromium are available in all forms, cast or wrought, and if the proper precautions are taken may be hot and cold worked, machined and welded almost as readily as ordinary carbon steel. The welding rod unless otherwise specified should be of such an analysis that the deposited metal will conform to the composition of the parent metal; care being taken to allow for the losses of chromium or other elements, and carbon pick-up. Preheating the work to temperatures of 300 to 400 deg. F. is desirable to prevent excessive air hardening and possible cracking during or immediately following welding. Immediately after welding the equipment should be annealed to obtain the maximum physical and corrosive resistant properties of the metal.

For Severe Conditions

The straight chromium alloys containing from 15 to 30 per cent chromium are used for resistance to abrasion and to highly corrosive media at temperatures up to 2000 deg. F., which includes temperatures far above those at which carbon steel can be safely used. Chromium alloy steels are most satisfactory for use under oxidizing conditions which cause the formation of a protective chromium oxide surface film. The rate of corrosion is determined by the ability of the process solution to build up or heal this film as it is broken by abrasion or attack by other agents in the process. An outstanding example of this action is the use of 15 or 28 per cent chromium steels for the handling of mixed sulphuric and nitric acids in the explosives industry. The oxidizing nitric acid passivates the surface of straight 15 to 28 per cent chromium alloy rapidly enough to nullify the attack by the reducing sulphuric acids. As the chromium increases, the resistance to both corrosion and oxidation is increased. However, increasing the chromium content accelerates grain growth in

A lining of chrome-nickel steel protects the interior of this separator

these steels at high temperatures. Because of this condition the high chromium-nickel or nickel-chromium alloys are recommended for cases requiring both strength and oxidation resistance at high temperatures.

The addition of nitrogen, nickel, molybdenum, and silicon have greatly increased the utility of the ferritic 15 to 28 per cent straight chromium steels. In order to retard grain growth and improve the ductility and toughness of the straight chromium alloys, nitrogen is added to the extent of approximately one part of nitrogen to 120 parts chromium. Nickel introduces a secondary austenitic phase, the presence of small quantities of which results in the formation of a duplex structure which makes possible a wide variety of physical properties by heat treatment. For example, the 16 per cent chromium, 2 per cent nickel alloy known as "two-score," is

Varnish kettles of stainless steel last under long and severe service

used where a combination of high strength, corrosion and shock resistance is required. Steel which contains 25 per cent chromium, 5 per cent nickel, 1.50 per cent molybdenum may be heat treated to give a hardness of 400 Brinell. It is used for piston rods or valve seats to prevent seizing or galling in corrosion resistant alloy steel pumps and valves for handling sulphite liquors in the paper and textile industries. The addition of nickel and molybdenum further increases the corrosion resistance to reducing conditions. It has been reported that approximately 1 per cent silicon improves the corrosion resistance of the 28 per cent chromium alloy to phosphoric acid.

The alloys in this group are available as castings and all forms of wrought shapes. They may be hot worked, cold formed, machined and welded to make any type of equipment if suitable precautions are taken. The single phase ferritic alloys are non-hardening and the grain structure cannot be refined by heat treatment. Grain refinement is accomplished only by cold working. To obtain the maximum corrosion resistance and ductility these alloys must be stress relieved at temperatures of 1400 to 1450 deg. F. Because of the effect of grain growth on the ductility and toughness of the metal it is important that these alloys are not overheated during their manufacture or during fabrication. When welding heavier sections, especially in cold weather, the equipment should be preheated to avoid cracking of the weld deposit. Better ductility and sounder welds are obtained by laying small beads and refining the grains of the deposit metal by peening. After fabrication all chromium-iron vessels should be stress relieved to relieve strains set up by forming and welding.

Austenitic Alloys

When nickel is added in increasing quantities to the low carbon straight chromium steel containing about 18 per cent chromium, the structure changes from a single phase (ferrite) to a duplex phase (ferrite and austenite) and finally again to a single phase (austenite). The minimum amount of nickel required in an 18 per cent chromium steel to make it completely austenitic is approximately 8 per cent. By maintaining the correct ratio of chromium to nickel, the austenitic chromium-nickel steels commonly known as 18–8, 25–12, and 25–20 were developed. As shown in Table I (see Data Sheet section, p. 645) all three alloys have exceptionally good resistance to oxidation and to creep at high temperatures. This class of high alloy steels is used more extensively than the other types and has been found most satisfactory for applications requiring resistance to a combination of oxidizing and slightly reducing media. Where ductility is of prime importance they are often substituted for the straight chromium steels even under oxidizing conditions such as in processes handling nitric acid or related products. These steels are not resistant to strongly reducing conditions involving sulphur and chloride compounds. Special steels which will be discussed later have been developed for this purpose. Modifications of the 18–8 and 25–12 compositions include the addition of molybdenum, tungsten, silicon, copper, manganese, columbium, titanium, nitrogen, sulphur, selenium and zirconium. The addition of approximately 3 per cent molybdenum, tungsten or silicon improves the creep strength and oxidation resistance. Molybdenum also increases the resistance of the steel to the pitting type of corrosion that occurs in processes where the solutions are slightly reducing in nature, such as weak hydrochloric acid, chloride salts, sulphurous acid, and sea water. The molybdenum bearing compositions have been very successful in resisting corrosion in the vapor phase of a number of organic compounds such as acetic and propionic acid in which phase the regular 18–8 and 25–12 compositions fail. In the liquid phase the 18–8 and 25–12 compositions are entirely satisfactory. The presence in the steel of copper up to 1.00 per cent may form copper salts in the reaction which may inhibit corrosion of the equipment. Manganese up to 2.50 per cent improves the hot and cold working properties especially in the molybdenum, columbium and titanium bearing compositions. Columbium and titanium, usually to the extent of less than 1 per cent, are added to prevent susceptibility to intergranular attack after the alloy has been exposed to temperatures between 800 and 1600 deg. F. There are some applications where titanium has an adverse effect on the corrosion resistance of the steel but we do not know of a single case where the presence of columbium is detrimental to overall corrosion resistance.

Small amounts of selenium, zirconium, or molybdenum with sulphur are added to improve machinability. The elements used to promote machinability sometimes have an adverse effect on corrosion resistance and should not be used when corrosion is a major factor unless tests show that this type of steel is satisfactory for the intended service.

Another important composition in this group contains 18 per cent chromium, 8 per cent manganese. This composition may be modified by the

addition of nickel or copper or both to replace part of the manganese. These steels are more effective than the straight chromium-nickel variety in resisting certain corrosive conditions involving sulphurous and sulphide gases.

The austenitic steels cannot be hardened by heat treatment but they can be hardened and strengthened by cold working to give a tensile strength of 200,000 lb. per sq. in., retaining sufficient ductility for structural purposes. However, cold working decreases their resistance to highly corrosive media.

In general, steels of this group have a single phase austenitic structure and are non-magnetic, but certain compositions like the 18 chrome, 8 nickel, 3 molybdenum, and 25 chrome, 12 nickel, and 18 chrome, 8 manganese steels have duplex structures containing austenite and ferrite and these are slightly magnetic. If steels containing this duplex structure are held for prolonged periods at temperatures between 800 and 1600 deg. F., carbon is precipitated out in the ferrite phase causing brittleness and accelerated corrosion in the ferrite area when exposed to certain corrosive media.

The austenitic chromium-nickel and chromium-manganese steels are available as castings and in all the usual commercial forms of wrought products. They are readily fabricated by the usual methods of hot and cold forming, machining, welding and brazing. Detrimental structural changes caused by severe cold working during fabrication or exposure to temperatures between 800 and 1600 deg. F. should be corrected by heat treatment. Heat treatment can be eliminated by using the columbium or titanium bearing stabilized compositions. The stabilized steels make the equipment more flexible, and facilitate plant maintenance. In addition, the stabilized material, which is not susceptible to intergranular corrosion at any temperature, is necessary for construction of pressure vessels that require stress relieving. The stabilized alloys are generally welded with a columbium-bearing rod containing about 2 per cent manganese and about 0.70 per cent silicon.

Alloy steels for resistance to abrasion are discussed on page 587 of this issue of *Chem. & Met.*

Special Alloys

A number of special alloys have been developed to meet extremely severe conditions of temperature and corrosion. Chromium-nickel and nickel-chromium alloys containing 30 per cent chromium, 25 nickel; 25 nickel, 15 chromium; and 35 nickel, 18 chromium; are used principally as castings for furnace parts, carburizing and annealing boxes up to temperatures of 2500 deg. F. Higher nickel alloys containing 60 to 80 per cent nickel, 20 to 30 chromium are also used as castings and in wrought forms for heat and corrosion resistance. Alloys containing 60 per cent nickel, 20 to 30 molybdenum, 20 iron, sometimes modified by chromium and silicon, are suitable for equipment used in processes where they are subjected to a wide variety of concentrations of sulphuric and hydrochloric acids from room temperature to near the boiling point of the acids. These alloys may be readily welded. All are available as castings, same may be obtained in wrought form and all except the high silicon alloy may be machined. Other alloys containing 35 per cent nickel, 15 chromium, 2 to 3 silicon, 3 to 4 molybdenum, available as castings only, are used for valves and pumps in handling warm sulphuric acid of all concentrations.

Alloys for Low Temperature Service

Recent developments in the chemical and oil industries requiring equipment for refrigeration, pressure vessels for liquefaction of gases and dewaxing of oils at extremely low temperatures, have resulted in considerable research on the physical properties of alloy steels at temperatures from 0 to —300 deg. F. When low carbon steels are exposed to sub-zero temperatures the only significant change that occurs in the physical properties is an extreme reduction in impact strength or resistance to shock. Several investigators have shown that the impact value in low carbon steel can be improved to give satisfactory service at temperatures from 0 to —175 deg. F. provided the steel is thoroughly deoxidized and given a normalizing treatment to obtain grain refinement. To get further improvement it is necessary to resort to alloy steels. This is illustrated in the paper by A. B. Kinzel, Walter Crafts and John J. Egan entitled, "Fine-Grained Structural Steels for Low Temperature Pressure Vessel Service." (American Institute of Mining and Metallurgical Engineers, Feb. 1937). The authors found that: "Aluminum, vanadium, zirconium and columbium when added to plain carbon or low-alloy steels in sufficient amount to produce grain refinement result in improved retention of impact strength at low temperatures. Aluminum-killed, normalized, plain carbon steels of otherwise appropriate analysis, in small sections are satisfactory for engineering service at temperatures down to approximately minus 80 deg. C. (minus 112 deg. F.). Chromium copper aluminum-killed low-alloy steels are satisfactory for engineering service at temperatures down to minus 100 deg. C. (minus 148 deg. F.) and may be used in larger sections."

Other alloy steels that were found satisfactory from 0 to —200 deg. F. were 2.5 per cent nickel, 1 copper; 2 nickel, 0.50 vanadium, 0.50 to 1.00 zirconium; 1.5 manganese, 1.00 zirconium; and 3 nickel, 1.00 zirconium. For temperatures below —200 deg. F. only the higher alloy austenitic steels such as the 18 per cent chromium, 8 nickel type are satisfactory.

Nickel-chrome tubes are used in high heat zone of this annealing furnace

The low temperature, low alloy steels are available in all forms and may be worked and fabricated in the same manner as carbon steel. Because of the effect of grain size on low temperature impact, care must be taken not to overheat the steels during forming operations unless subsequently normalized. After fabrication the equipment is stress relieved at 1100 to 1200 deg. F.

HIGH-SILICON IRONS

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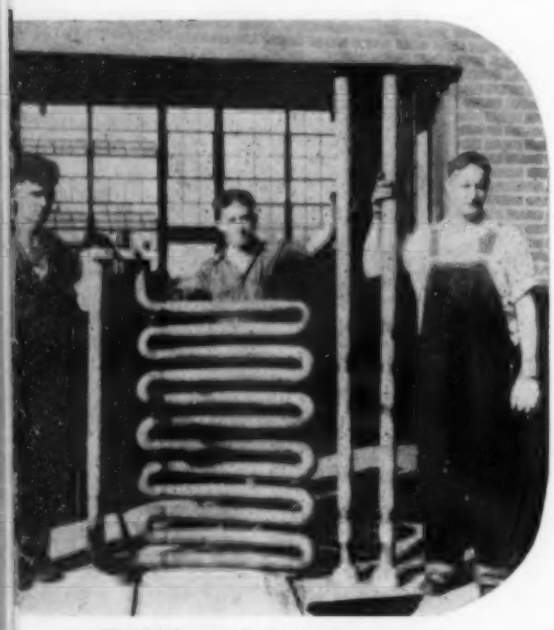
BY THE TERM "HIGH SILICON IRONS" is meant cast irons containing from 14 to 15 per cent silicon. These extremely hard and somewhat brittle alloys offer greater resistance to acid corrosion than do most other metals. Also, they are resistant to a wider range of chemical corrosion. Though available only in castings, there are a number of standard stock forms which can easily be welded into special equipment.

A good high-silicon iron contains from 14.35 to 14.75 per cent silicon and not more than 0.85 per cent carbon. The tensile strength runs from 15,000 to 20,000 lb. ultimate, the compression strength much higher. Castings weighing as much as 10,000 lb. are now being produced.

The physical properties of high-silicon iron castings are greatly improved by a thorough normalizing treatment to eliminate strains, although this does not affect the grain structure. The best practice also includes pickling in an acid bath to thoroughly clean the castings and bring to light any shrink or slag inclusions. Due to the high coefficient of expansion as compared with gray iron, and the fact that it is hardly practicable to use chaplets except in special cases, special designing and special pattern equipment are required. From a practical standpoint, however, any castings that can be made in gray iron can be made in the high-silicon irons.



Weld-fabricated high-silicon cast iron coil for use in strong acid

Extreme hardness is an outstanding characteristic of the high-silicon irons. Since machining with cutting tools is not practicable, all finishing must be done on grinding machines. Close machining tolerances can be maintained.

Because it is not possible to thread high-silicon iron castings satisfactorily, flanged connections are in universal use. In some cases, carbon steel or alloy steel inserts are cast in and tapped. These prove satisfactory where the joint is not submerged. Holes larger in diameter than the thickness of the casting can be satisfactorily cored. Holes smaller in diameter than the thickness of the casting can be made by casting in steel inserts which are later eaten out by acid. This leaves a clean hole of true diameter.

High-silicon irons are chemically resistant to a wide range of corrosive liquids and gases. They are not recommended, however, for strong alkalis, fluorine compounds, sulphites and sulphurous acids. Low strength hydrochloric acid at room temperature can be handled satisfactorily. Concentrated hydrochloric acid at elevated temperatures, as well as hot ferric chlorides, act on the ordinary high-silicon irons. These chlorine compounds can be successfully handled in a special high-silicon iron which in addition to the silicon contains from 3 to 4 per cent molybdenum. This particular alloy, known as Durichlor, will handle all strengths of hydrochloric acid at temperatures up to boiling. However, it is affected by wet chlorine gas at elevated temperatures and cannot be recommended for mixtures of chlorine gas and steam. Durichlor has the same physical properties as the standard high-silicon irons and as far as production and design are concerned may be classed among the standard high-silicon irons.

Design and Fabrication

To offset the low tensile strength of the high-silicon irons, engineers have shown considerable ingenuity in the matter of design, so that today almost any piece of equipment can be successfully produced in the high-silicon irons.

Pressures as high as 100 lb. per sq. in. can be safely handled. Pipe joints are generally made by casting on the end of the pipe or fitting a bead which is machined for a gasket joint. The two pieces are then joined by a flexible malleable iron split flange. In some cases, block type installations may be preferable.

In designing equipment which must undergo considerable temperature change, the matter of distribution of metal is of great importance, as is also the matter of normalizing castings by heat treatment.

So successful has been the adaptation of high-silicon iron in fabricating various types of equipment that a wide line of standard items is now available for plant service. This includes several types of valves from one-half inch to twelve inches in size, and centrifugal pumps in sizes from one inch to ten inches and capacities up to 2,500 g.p.m. at heads up to 125 ft. of water. Centrifugal pumps are available in the self-priming as well as in the standard types. Reciprocating pumps are manufactured in capacities up to 50 g.p.m., and for pressures up to 125 lb. per sq. in. A full line of pipe and fittings up to 10 in. inside diameter, ejectors, siphons, heating jets, heat exchangers, heating and cooling coils, anodes, exhaust fans, tank connections, hose connections, reaction kettles, denitrating towers, dehydrating towers, absorption towers and condensers, are standard stock items, as also are high-silicon iron parts for sulphuric and nitric acid concentrators. One manufacturer has available as many as 26,000 items.

In addition to special castings which are made to customer's design, it is possible to fabricate special equipment by welding, using standard stock forms. The high-silicon irons are easily welded with a gas flame. Careful preheating and cooling are necessary, and normalizing is desirable in order to eliminate any strains which possibly may have been set up by welding. The welds are homo-

geneous and are as acid-resisting as the balance of the casting.

High-silicon iron castings do not depend on a coating or surface treatment for their corrosion resistance. They are acid-resisting throughout. Their hardness quite often is a very valuable asset, as they afford resistance to abrasion as well as corrosion. This is a decided advantage when handling acid slurries or muddy solutions at high velocities. Perhaps their greatest disadvantage is their low resistance to shock, although this can be overcome to a large extent by proper design of castings and proper handling.

High-silicon bell and spigot pipes and fittings are ideal for handling the corrosive wastes from laboratories and for handling corrosive process liquids or gases at pressures within the limitations of a caulked joint. The installation is made according to common plumbing practice, but asbestos rope is used in place of the usual oakum packing. Lead is caulked on the asbestos packing in the usual way.

As a material of construction for plant purposes, high-silicon acid-resisting irons cannot be underestimated in their value to the chemical industry. The shortcomings of materials to which the chemical engineer and manufacturer of corrosive chemicals was formerly limited, such as stoneware, glass, quartz, noble metals and metals of a more or less corrodible nature, have long been recognized, and chemical industry has now learned to appreciate the superiority of ferro-silicon or acid-resisting cast irons for dealing with acids and corrosive liquors. Continued research and experiment have made it possible to deal with these difficult alloys in such a way as to insure greater stability, improve the tensile strength and render castings, vessels and parts homogeneous—the attainment of which some ten or twelve years ago would have been considered almost impossible.

In designing casings to be produced in high-silicon iron, the question of plane surfaces must be considered. Large flat areas should be avoided, but if necessary, they should have a length two or three times their width. Abrupt changes of section and sharp corners should be avoided. Containers of any form should have a reinforcing bead at the top edge. In making patterns a shrinkage of $\frac{5}{32}$ in. per foot should be allowed.

ABRASION RESISTANT ALLOYS

ALMOST EVERY process industry plant is concerned with excessive wear of equipment due to grinding, crushing and to a lesser extent to the action of sludge. This abrasive action can be combatted by the use of any one of several types of resistant materials. Among the most important are the following: the metal that is hard throughout, an ordinary metal whose surface is hardened, and an ordinary metal which is covered with a layer of about $\frac{1}{8}$ in. of hard surfacing material.

These resistant metals will increase by several fold the life of a piece of equipment subjected to great wearing action, and will result in direct economies because of the fact that the hard metal or special surfacing treatment generally costs much less than the purchase price of the replacement parts that would otherwise be necessary. In addition, indirect savings are effected because it is not necessary to shut down the machine as frequently for repairs. Some of these abrasion-resistant materials are also corrosion-resistant.

The useful life of the equipment that is subjected to a combination of severe shock and abrasion can be prolonged by constructing it of manganese steel. The usual composition is 12 to 14 per cent manganese and 1.10 to 1.40 per cent carbon. However, in some cases small amounts of nickel, chromium, molybdenum or copper are added in order to secure special characteristics. For example, the addition of 3 per cent chromium and 1.50 per cent copper increases the work hardening effect and raises the yield point approximately 25 per cent. The higher yield point makes the steel suitable for applications involving heavy impact which would cause flow in the standard manganese steel.

The manganese steels are quenched from 1800 deg. F. to give a relatively soft alloy that hardens rapidly when cold worked. It is this property that makes them important abrasion-resistant materials. Since they are very difficult to machine, most manganese steels are fabricated either by casting or hot forging.

If the equipment to be constructed is expected to resist unusually severe abrasion but only little shock, and no great strength is required, one of the high-chromium alloys (25 to 30 per cent chromium and 2.5 per cent carbon) can be specified. These alloys generally are used in the as cast condition. Examples of their application are mill liner plates, chute linings and dry-pan runner plates.

Where shock is not a factor, several steels of low alloy content have proved useful. They contain small amounts of chromium and molybdenum and sometimes nickel. Practically all of the low alloy steels are machinable, and their best properties are brought out by heat treatment.

Cast irons containing small amounts of alloying elements are finding general use in the process industries for abrasion resistance. Chromium is the principal addition element, but nickel, molybdenum, vanadium and copper are often added to obtain special properties, such as resistance to shock.

54-in. dia. crusher rolls built up on surface with hard-facing alloy

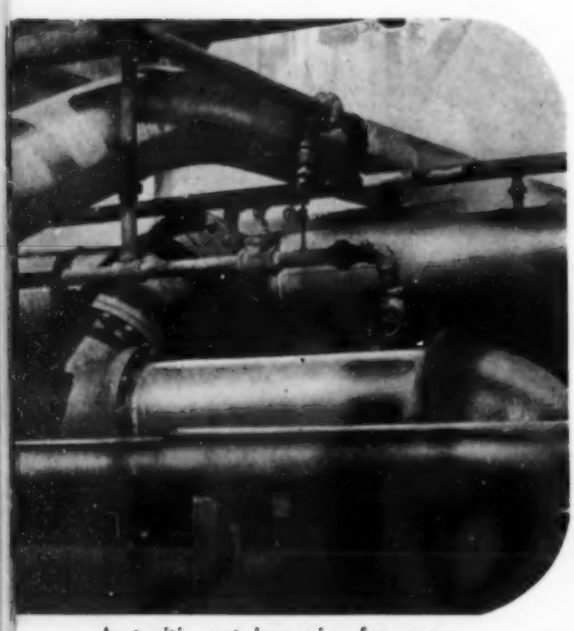
The use of hard-facing alloys has long been recognized as one of the most satisfactory and efficient means of combatting abrasion. The part to be protected is covered with a thin layer of fused alloy. There are a number of alloys used for this purpose, but the following have found the widest application: an alloy of cobalt, chromium and tungsten; a self-hardening chromium-manganese-iron alloy; and a cast tungsten-carbide available in several forms.

PLAIN AND ALLOYED CAST IRONS

EDITORIAL STAFF

CAST IRON IS NOT CORROSION RESISTANT to as large a number of chemicals as are the stainless steels and other special alloys, but it does possess sufficient immunity to make its use economical in many cases where corrosion is a factor. The facility with which it can be cast into as intricate a shape as the designing engineer can imagine, its ease of machining, ability to withstand fairly high pressures, and low cost, recommend it for many applications. In recent years cast iron has been improved in quality by refinements in foundry practice, by altering the basic ratios of carbon and silicon, and more recently by the addition of alloying elements.

Cast iron is favored in many instances because of its reliability, and because it may be cast in a simple piece; thereby eliminating joints which are a frequent source of trouble. The use of cast iron also eliminates the possibility of any galvanic action at the point of contact between different metals, or between a weld and the adjourning metal. As W. H. Rother (*Chem. & Met.* vol. 40, p. 350) has pointed out it can be made in such manner that the dimensions will be sufficiently accurate to allow the use of close fitting working parts, as for instance, kettles with close fitting agitators.



Austenitic cast iron pipe for gasoline vapors containing HCl and H_2S

Frequently the design of a casting plays an important part in its life. As R. N. Stubbs Jr. has stated in the *Iron Worker*. If a lead kettle two inches thick lasts two years, it is not necessarily true that the same casting four inches thick will last four years. It may go out in six months because the extra wall thickness requires a much higher temperature on the outside to obtain the same temperature on the inside. The difference in expansion between the outside and inside layers may set up sufficient stress to crack the casting after a very short life. And it is known that square corners in any vessel are dangerous, the danger increasing with higher temperatures. Sudden changes in section size are to be avoided.

An important disadvantage to cast iron for use at high temperatures has been its tendency toward growth, as much as 30 per cent increase in volume in some cases. Through the use of alloys and better melting, this characteristic can now be controlled almost to the vanishing point and cast iron is now recovering a good deal of the ground lost in this direction.

An outstanding advantage of cast iron is its rigidity at all temperatures under its melting point and at all safe working pressures. It is almost the only metal which does not sag or otherwise change its shape under these conditions.

For solutions with alkaline or neutral reaction, the use of cast iron is almost unlimited. It is resistant to the action of sulphur and sulphides and, in the absence of moisture, to gases such as chlorine and sulphur dioxide. In addition, cast iron has many important applications as an acid resistant material provided due consideration is given to the nature and the concentration of the acid.

Hard cast irons are useful where abrasion is an important factor. While hardness does not vary directly with resistance to abrasion, increased hardness in cast iron results in greatly improved performance in applications involving severe wear. Alloy cast irons have been developed which possess a hardness ranging upward to 700 brinell. These alloys have found wide use in applications such as pump casings, grinding disks, and conveyor screw flights.

Alloy additions to cast iron, made in order to increase resistance to corrosion, must be carefully adjusted to the actual conditions to be met and the composition must be correctly balanced, warns H. L. Maxwell (paper presented before the Chemical Engineering Congress of the World Power Conference, 1936). He states that it often happens that a particular composition will give a marked improvement under one set of conditions, while in another application the rate of corrosion will be increased. Nickel-chromium additions are usually beneficial although a small amount of chromium alone is often detrimental to corrosion resistance. The improvement in low-alloy nickel-chromium irons is probably due, in the main, to better physical properties.

Vanadium and titanium are used only in small proposition and serve to refine and deoxidize the metal. Copper is attracting attention at this time in small amounts in castings. While the amount of copper that is soluble in plain cast iron is limited, the proportion can be increased if certain other metals are present.

Cast irons containing sufficient nickel or nickel and copper to produce a stable austenitic structure in the normal casting operation were developed several years ago. Resistance of these irons to heat and chemical attack has resulted in a relatively broad application in process industry equipment. They have a higher coefficient of thermal expansion than the ordinary product, and a lower thermal conductivity. The comparative ductility and easy machinability give them considerable advantage. Rotary and reciprocating pumps, valves, pipe lines and reaction vessels operating on sulphuric acid mixtures, petroleum refinery liquors, caustic and numerous salts, show economies when fabricated of austenitic cast iron.

Another important group of cast irons consists of those containing about 14.5 per cent silicon. These are used mainly where resistance to sulphuric acid is required. They are discussed at length on page 586.

LEAD AND LEAD-LINED

By E. T. CRAWFORD, JR.
Carbide and Carbon Chemicals Corp., South Charleston, W. Va.

LEAD SERVES THE MODERN CHEMICAL ENGINEER for process piping and equipment. It is a useful material in equipment for handling dilute sulphuric and sulphurous acid solutions, phosphoric acid, hydrofluoric acid, in the sulphate process for pulp and paper making, and for sulphonation, bromination, and chlorination processes in the organic chemicals industry. It is valuable as a material of construction because the metal can be readily formed into the necessary shapes from sheet or pipe, and joined by welding or "lead burning."

Lead is readily available to the fabricator as: rolled sheets from 3/32 in. to 1 in. in thickness; seamless extruded pipe from 3/8 in. to 6 in. inside diameter with any required wall thickness; castings of any shape or size; and lead homogeneously bonded to steel sheet and iron or copper pipe for mechanical support and added strength. The gage of sheet lead is determined by its weight in pounds per square foot. A sheet 1 in. thick weighs 60 lb. per sq. ft.; so for lighter stock each pound per sq. ft. is equivalent to 1/64 in. in thickness without serious error. The usual pipe sizes are described by the Lead Industries Association Standards for A, AA, and AAA pipe that will withstand 50, 75 and 100 lb. gage pressure of cold water, respectively. Extruded shapes can be made in any required form for which a die can be made. The American Chemical Industry uses these forms made from chemical lead, hard lead alloys with various percentages of antimony, and tellurium lead. Chemical lead is virgin, undesilverized lead of at least 99.92 per cent purity, produced from the ores of the southeastern Missouri district. It is commonly known as St. Joe lead, and is distinguished from European chemical lead by its copper content of 0.05 to 0.08 per cent uniformly distributed through the metal. The copper content increases the tensile strength and hardness of the lead without reducing its corrosion resistance.

Tensile Strength of Lead Alloys

Type of Lead	Purity Per-cent Lead	Ultimate Tensile Strength Lb./sq.in. at 60 deg. F.
Pure Electrolytic	99.999	1,609
English Chemical	99.99	1,960
St. Joe Chemical	99.93	2,760
St. Joe Tellurium	99.84	3,350
Antimonial, 6 per cent	93.9	4,500

The additional strength has made American chemical lead superior in service when compared with English lead of 99.99 per cent purity.

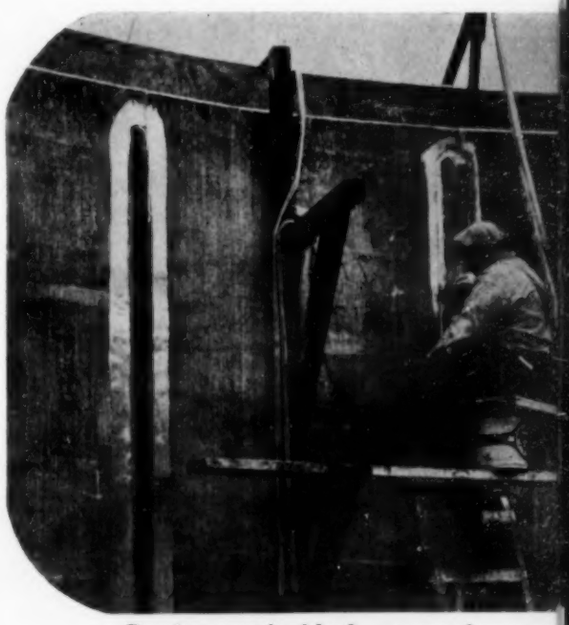
Hard lead may contain from 4 to 14 per cent antimony added to make a stronger, harder metal at temperatures under 245 deg. F. but it is always more brittle than chemical lead. The eutectic of lead-antimony, containing 12 per cent antimony, melts at 477 deg. F., or 154 deg. lower than the melting point of chemical lead. Consequently, the tensile strength of hard lead alloys decreases rapidly at temperatures above 212 deg. F. The alloy most used for valves, or piping, or equipment contains 6 to 8 per cent antimony. It has a melting range of about 100 deg. F. instead of a definite melting point (621 deg. F.) as is the case with pure lead. The wide plastic range makes the alloy most suitable for making sound castings without shrinkage voids.

Tellurium lead was a valuable development of English research directed toward improving the strength of chemical lead. It was found that the addition of 0.06 per cent tellurium made a solid solution that raised the temperature of re-crystallization of pure lead from —22 deg. F. to about 212 deg. F. for the alloy. More than 0.08 per cent tellurium content caused separation of lead telluride particles at the grain boundaries which proved to be an undesirable condition for corrosion resistance. The alloy is now made for the American trade from St. Joe lead and has proved most satisfactory where stress, vibration, or hot solutions caused failures of chemical lead.

Physical Properties and Design

Lead is a soft, malleable, ductile metal of little mechanical strength. All lead is crystalline, but it acts like a plastic material under stress, creeping or flowing into new shapes. Lead is the only common metal of construction that is always used at temperatures above its re-crystallization temperature and often close to its melting point. It tends to relieve an applied stress by grain growth or new structure, whereas iron would become work-hardened and resist further change in shape. The creep characteristics and malleability of iron at 2,075 deg. F. would be analogous to chemical lead at a temperature of 212 deg. F. The increase of 234 deg. F. in the re-crystallization temperature resulting from the addition of tellurium makes this alloy capable of being refined to a very fine crystalline structure by cold work and being permanently work-hardened. Tellurium lead is more resistant to deformation under strees than chemical lead without being brittle like the antimony alloys.

These physical characteristics make it comparatively simple for a skilled lead worker to fabricate very complicated shapes in the construction of equipment. They also explain why a great number of failures in service of chemical equipment can be attributed chiefly to mechanical weakness. Lead is readily stretched beyond its elastic limit and the resultant permanent set causes sheet or pipe to sag or creep. The movement may crack the protective surface coating and cause cracking of the metal by a combination of stress and inter-crystalline corrosion.

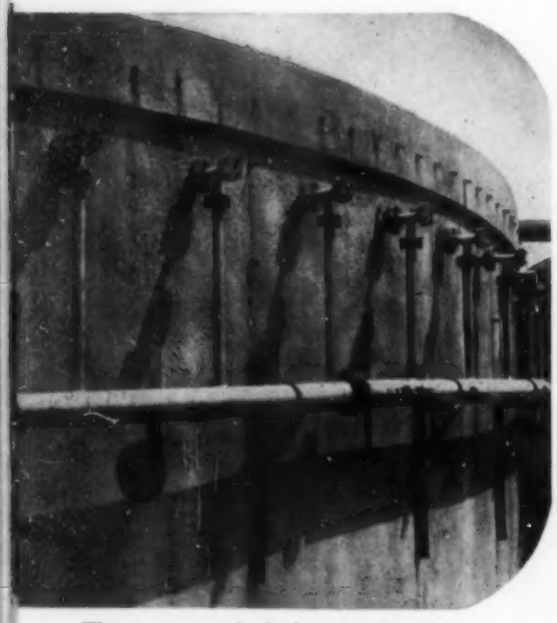


Burning a patch of lead over a steel supporting strap in a lead-lined tank

The metal must be adequately supported or fixed in position to prevent such failures.

Strength Added by Bonding

Bonding the lead homogeneously to a stronger metal is a logical solution for the problem of support. Unfortunately, lead cannot be alloyed with either iron or copper. A third mutual alloying agent must be used with a flux to keep the surfaces free from oxides. Tin, antimony, mercury, or some of their reducible salts are used with a flux of zinc chloride to prepare the surface for the application of lead. The lead may be applied either by lead burning parallel seams manually to cover the entire surface, or by casting a section enclosed by a mold. The cast lead is heated and cooled from the steel side, then hammered to break down the coarse cast structure, and finally scraped to the required uniform thickness. Heating coils are made by bonding lead to copper pipe and bending the pipe into cylindrical or helical shapes.



The proper method of supporting a lead pipe to prevent heat sagging

Homogeneously bonded lead is not universally used because of the high initial cost of preparing and fabricating the bi-metal equipment and the probability of flaws in the lead coating that may become failures in very severe service. The lead coating may be examined for pinholes by etching it with dilute nitric or hydrochloric acid.

Most lead tanks are made by mechanically attaching lead sheets to steel or wood tanks by steel bolts and straps, then covering the exposed steel with patches. The lead may also be supported by building an acidproof masonry wall on one side and holding the lead firmly against the masonry with wooden slats or sheet steel. The masonry protects the lead from erosion and it insulates the metal from solutions at high temperatures. Piping is usually clamped to steel straps in vertical runs, and laid in steel angle, channels, or in brick or wooden troughs for horizontal positions. Lead heating or cooling coils are made from extruded pipe wound into a spiral or helical shape and supported on solid lead blocks between each turn. A graph appearing in the Data Sheet section, page 635, shows the safe allowable fiber stress which may be used in the design of coils and piping made of three kinds of lead. The required thickness for holding the pressure may be calculated from the formula

$$T = \frac{P\,D}{2\,S}, \quad \text{where}$$

T is thickness of pipe wall in inches,
P is safe working pressure in lb. per sq.in.,
D is inside diameter in inches,
S is maximum allowable fiber stress (may be obtained from graph).

An additional thickness for corrosion resistance should be added dependent upon the character of the service required.

Steam used for heating coils should not be super-heated because the high temperature of the inlet steam will result in rapid failure of the pipe.

Lead Burning

Lead burning is a process of uniting pieces of lead by fusing them in an oxy-gas flame. No practical flux for keeping the surface clean of oxide has been found, so the burner must prepare the pieces by scraping the surfaces free of oxide just before melting the metal under the envelope of a reducing flame. Oxy-hydrogen is preferred by lead burners to other gaseous combinations because:

(1) The gases have a comparatively low temperature of combustion. (2) Oxygen and hydrogen burn freely in all proportions from 4 to 74 per cent hydrogen, and (3) The wide range of gas adjustments possible make the flame a general utility tool for cutting or building different seams. The outside envelope of the oxy-hydrogen flame is inherently oxidizing, and unless properly handled by an experienced mechanic, it will make a joint saturated with oxide. If the burns corrode preferentially in an acid solution, it may be the result either of the added burning bar containing dross, the failure to scrape the surfaces clean in preparation for burning, or the use of an oxidizing flame.

The preferable seam is the horizontal or flat burn because molten lead can be flowed rapidly in such a position. The work will proceed rapidly, and the seam should have good penetration into the base metal. It is most economical to plan the work so that burns can be made in a horizontal position by rotating the tank, or building a wooden frame to hold the lead while fabricating it. Upright lap seams require considerable time and one bad lap can cause a leak. Pipe joints should be made by rolling the pipe to make a simple butt joint when it is possible. When the pipe must be maintained in position, the joint is made by burning the lower portion on the inside and completing it on top by covering a split or a cap on the pipe.

Burns made with tellurium lead should be hammered lightly to work-harden the metal and refine the coarse cast structure so that it will be similar to the rolled sheet or extruded pipe.

Corrosion Resistance

The resistance offered by lead to solution in sulphuric acid is due largely to the dense, adherent protective coating of neutral lead sulphate formed on the metallic surface by initial attack of the acid. This can be demonstrated readily by scraping a surface and immmediately dropping it into acid. It will be attacked rapidly and displace hydrogen from the acid. In a short time the bright surface becomes covered with sulphate and action ceases. Lead forms two salts with sulphuric acid, the neutral sulphate and the acid sulphate. The neutral salt is practically insoluble in water or dilute acid. The acid salt is only stable in concentrated sulphuric acid, in which it is relatively soluble. Its solubility increases with the temperature. Consequently, lead equipment that is not protected by masonry linings should not be used for boiling sulphuric acid of more than 55 per cent strength. (See graphs in Data Sheet section, page 635.)

Resistance of lead to sulphurous,

phosphoric, and hydrofluoric acids is similar to the action in sulphuric acid. The corrosion resistance of the metal is materially reduced by small amounts of tin, bismuth, zinc, and lead oxide or "dross." The impurities precipitate at the grain boundaries as a separate phase, and are readily attacked by acid solutions to disintegrate the metal into a granular mass. The same preferential attack was observed in some early field tests of tellurium lead in which the tellurium content exceeded 0.08 per cent and the structure was not homogeneous.

Lead is very susceptible to attack by aqueous solutions of organic acids, such as formic, acetic, or butyric, to form soluble lead salts leaving the metal surface exposed to further attack. Lead is rather rapidly dissolved by pure water or wet steam in the presence of oxygen. This action has been observed where lead pipe was used for conveying soft water or steam condensate. It can be reduced by de-aerating the water by mechanical or chemical means, or by forming a protective coating by the addition of sodium silicate or calcium salts to the water.

Lead equipment, well designed, well fabricated, and used under corrosive conditions favorable to the metal, serves as a basic tool for manufacturing operations of the chemical industry.

Precautions

USERS of lead pipe are frequently prone to overlook construction details which mean much to the life of a particular installation; so the Lead Industries Association gives the following helpful suggestions.

Lead pipe is corroded to some extent by most soils. It is affected by muck, cinders, sand and clay in that order. Organic matter in the soil increases and good drainage decreases the rate of corrosion.

Free lime will corrode lead in the presence of air and moisture. Therefore, if lead pipe passes through concrete walls or comes in contact with concrete, cement or mortar, containing free lime, it should be protected with a coat of bituminous material or wrapped in tarred paper.

Lead pipe should always be supported, particularly hot water lines. A narrow wood strip is usually sufficient to prevent sagging. An illustration of this is shown on the opposite page.

NOBLE METALS AND ALLOYS

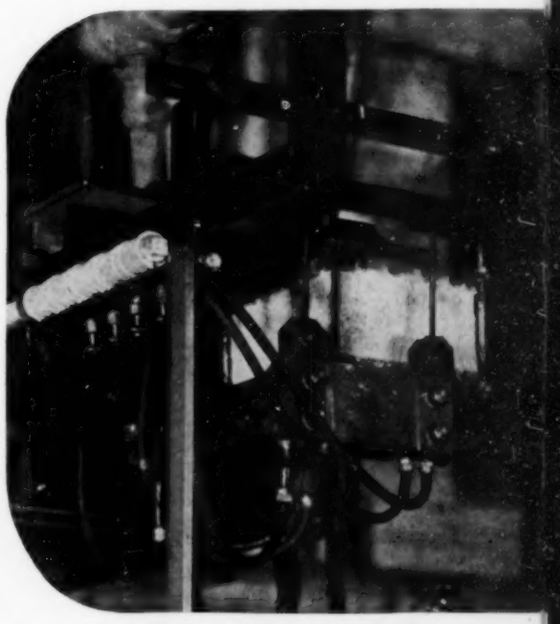
THE COMPARATIVE HIGH INITIAL COST of the noble metals has not prevented their use for construction of equipment, but in contrast to the lower cost materials, they are to be found in relatively small quantities and only in vital spots and for extreme conditions. These metals have an immensely important role, however, for in the places where they are used no other material may be substituted and, generally, upon their successful performance depends the success or failure of the operation of equipment or process.

This group consists of platinum, palladium, iridium, rhodium, osmium, ruthenium and gold. The first of these is the most important. It is a soft ductile metal but for commercial purposes is generally hardened by alloying with other metals. One of its most important properties is great resistance to acids and other troublesome chemicals. The resistance of platinum to aqua regia can be increased by alloying with iridium, osmium, rhodium or ruthenium. Strange to recount, although palladium dissolves readily in nitric acid, the platinum-palladium alloys containing as much as 25 per cent of the latter are practically unaffected.

It is possible to fabricate large pieces of equipment of practically any shape desired from platinum and its alloys, and repairs can be made in the plant without any particular trouble. In the glass industry a platinum alloy is used to cover the refractory pouring dies. The platinum-rhodium alloy prevents serious attack on the dies by the molten glass. Alloys of the precious metals are practically indispensable for the spinnerets in the rayon industry. The metals and alloys most generally used are: platinum, gold-platinum and gold-palladium. These materials withstand not only the wearing action on the extremely small holes but also the action of the acids and heat used in removing the hardened solutions that choke up the holes. Among the numerous other applications in the process industries should be mentioned furnace resisters, catalysts, anodes and parts of temperature recording instruments.

Gold and its alloys are in use for equipment in the production of pure chemicals. While the metal is suitable for some applications it is often alloyed with the platinum metals in order to harden it and to increase resistance to corrosion. Other metals that are added are copper and nickel, but they must, of course, be low in order to prevent attack by nitric acid.

In recent years precious metal clad equipment can be fabricated. Any of these more expensive metals on a heavy base metal are available. Clad metal has none of the porous characteristics of electroplated metals. The surface presented to the corrosive chemical is hard, dense precious metal—the precious veneer is in a layer as thin as 0.001 in. Layers of precious and base metal are fused together and rolled or drawn to finished dimensions. Nickel, brass, copper, and steel are used as the base metals, and they may be made as thick as necessary for strength.



Electric furnace making fibrous glass contains spinnerets of precious metal

These clad materials are available in sheets up to 48 in. wide, with the noble metal on one or both sides; in rods and wire from 1.5 in. diameter down to 0.005 in. diameter; in tubes from 1.5 in. diameter down to 0.0625 in. diameter with the noble metal on the inside, outside or both. Special shapes, with precious metal stripe inlays are also available.

COPPER CONSTRUCTION

By R. A. WILKINS

Revere Copper and Brass Incorporated, Rome, N. Y.

COPPER IS A MATERIAL OF CONSTRUCTION having great corrosion resistance plus malleability, ductility and a readiness of fabrication which make it a useful carrier for many chemical agents. Its physical properties, however, while adequate for many applications, limit its use as a structural material. On the other hand, in many instances strength and durability have been achieved without loss of corrosion resistance by using copper as a lining and by alloying copper with silicon, nickel, zinc, etc.

Indeed, certain alloys of copper not only retain but actually improve the corrosion resistance of copper itself and at the same time possess general physical properties far superior to those of the parent metal. It must be borne in mind, however, that when copper is alloyed for the purpose of increasing its tensile strength or hardness, some sacrifice of other physical properties is usually entailed. In general, alloys of copper lack the high electrical and thermal conductivity of the parent metal and in certain applications the reduction in these properties as a consequence of alloying is objectionable. In the construction of chemical equipment, however, the sacrifice can frequently be made without disadvantage.

Care, cleanliness and copper are the three C's of whisky's final quality

It is, of course, elementary to state that the basic virtue of copper in the chemical industries is the fact that as an element it does not displace hydrogen from acid solutions. In considering the use of copper in a given application, it is relatively simple to determine whether or not copper, as such, will be attacked by the material to be handled. To ascertain, however, whether copper as an engineering material is suitable for use in the commercial handling or processing of a specific reagent requires a full knowledge and consideration of the conditions of operation.

Attacked Primarily by Oxidation

Copper oxide is readily soluble in most acids and the introduction of entrained air in pumped acid solutions, or the introduction of any oxidizing agent in such solutions will result in an attack on the copper conduit or container. In the absence of entrained air, or other oxidizing agents, the life of copper in contact with many chemicals may be practically unlimited in a commercial sense. On the other hand, with the same materials involved, but with operating conditions which permit of oxidation of the metal, the life of the copper equipment may be relatively short.

In estimating the probable life in operation of copper equipment, the engineer should give careful consideration to his conditions of operation, which, rather than direct attack of the reagent upon the metal, may determine the service to be anticipated.

When the adaptability of copper or one of its alloys to a given set of operating conditions has been determined, the selection, as between copper and an alloy, or as between copper and competitive materials, will as a rule be based on a consideration of structural characteristics, construction costs and maintenance and shutdown costs.

Copper is a very ductile and malleable metal and can be readily formed, either hot or cold. It adapts itself readily to manual fabrication, an item of considerable importance where the number of units being constructed does not justify the cost of the fabrication of special tools for the stamping of headers and other parts. Copper can be joined to copper by conventional riveting methods, or by soft soldering, brazing with copper-zinc brazing alloys, gas or electric welding with phosphor bronze filler rods or with phosphor copper rods. When phosphor bronze filler rod is employed, it is frequently customary to chip out the weld on the inside of a vessel and to lay in a finishing bead of phosphor copper to cover the bronze seam for the purpose of preventing possible electrolytic action.

Not Easy to Weld

Copper, largely because of its high thermal conductivity, is not an easy metal to weld and, when employed, such operations should only be performed by skilled operators familiar with the special technique necessary. Where welded construction is planned, it is usually advisable to specify phosphor deoxidized copper or oxygen-free copper sheet and plate, even at a small premium over electrolytic copper. In general, welding as a method of construction is not recommended where the requirements call for thicknesses in excess of $\frac{3}{8}$ in. and in many applications $\frac{1}{4}$ in. may well be considered a maximum.

Where the chemical properties of copper are desirable, but design factors would necessitate the use of cumbersomely heavy gages, recourse is frequently had to the combination of steel as a structural material and copper as a lining material. In many applications lined equipment is a source of trouble. Failures of lining through erosion and mechanical damage and the troubles introduced by varying pressures can occasion high operating and maintenance costs.

Alloys of Copper and Silicon

Where the chemical properties of copper are desired, but its structural properties are deficient, and where, for any of several reasons, it is desired to avoid the use of steel equipment copper lined, recourse may be had to the silicon-copper alloys.

There are two general types of silicon-copper alloys, which for convenience can be known as type A and type B, the former containing more silicon and having greater tensile strength, the latter alloy being lower in its silicon content and more ductile. Typical physical properties of the

silicon bronzes are listed in a table at the end of this paragraph. These alloys are frequently sold under tradenames* by different manufacturers. As a general thing, such alloys contain in excess of 96 per cent copper with from 1.5 per cent to 3 per cent silicon and fractional percentages of other alloying constituents.

Physical Properties of Silicon Bronze Alloys

Property		Silicon Bronze Alloy Type A (High-Si)	Type B (Low-Si)
Tensile Strength, p.s.i.,	hard	120,000	90,000
	soft	67,000	42,000
Elastic Limit, p.s.i.,	hard	103,000	80,000
	soft	24,000	12,000
Elong. % in 2 in.,	hard	10	10
	soft	60	60
Rockwell B hardness,	hard	99	84
	soft	65	20
Melting Point, deg. F.		1,830	1,890
Density, Lb. per cu. in.		0.308	0.313
Coeff. of Thermal Ex.		0.000017	0.000017
Thermal Conduc., c.g.s.		0.086	0.116

The silicon-copper alloys are comparable to copper in their corrosion resistance. There are applications where the copper-silicon alloy appears to be somewhat superior to copper in this respect, but the superiority, where it exists, is not great. The advantage of the copper-silicon alloy is that its physical properties are far superior to those of the parent metal and, as the above mentioned table would indicate, the attainable physical properties are comparable to those of mild steel.

In the manufacture of chemical equipment, therefore, these alloys offer the opportunity of utilizing a material of construction which has adequate strength to meet the structural requirements and which at the same time possesses a resistance to corrosion fully comparable to that of copper itself.

While the cost per pound of the copper-silicon alloys exceeds that of copper in comparable gages, and while the material cost of solid copper-silicon alloy equipment is higher than the material cost of copper-lined steel equipment, there are economies of manufacture and maintenance shown by the former which, in many instances, swing the economic balance in favor of the alloy construction. Copper-silicon alloys can be autogenously welded by either gas or electric methods and welding is the most common method of construction used in the fabrication of tanks or other vessels of copper-silicon alloys. Any competent welder can be trained in the technique of welding the copper-silicon alloys, and the companies fabricating these alloys maintain welding consultants for the purpose of giving advice and instruction when necessary.

While it has been stated as a generality that the copper-silicon alloys will behave corrosion-wise in a manner comparable to copper, there are certain special conditions of stress and temperature which tend to produce intergranular corrosion. It is recommended, therefore, that the technical departments of the fabricating companies be consulted when new applications of these alloys are being contemplated.

In addition to the use of copper and the copper-silicon alloys as basic materials in the construction of chemical equipment, many of the alloys of copper are used extensively in special applications. Copper-silicon alloys, because of their excellent physical properties, are widely used for tie rods, lag screws, bolts and other types of fasteners where high strength is required and corrosion resistance necessary.

Alloys of Copper and Nickel

Alloys of copper and nickel containing 80 per cent copper, 20 per cent nickel and 70 per cent copper, 30 per cent nickel, are widely used for condenser and heat exchanger tubes. Engineering tubes in general are subject to service where the influence of erosion, entrained air and the impingement thereof on the metal surface, as well as the chemical action of oxidizing agents, is likely to be most severe.

Cupro-nickel is markedly more resistant to this type of attack than copper, or other copper-base alloys, and finds extensive application where the initial cost of the tube installation is of secondary importance in comparison with replacement costs and shutdown costs. The excellent properties, both physical and chemical, of the cupro-nickel alloys, are becoming more broadly recognized, with the result that an increasing industrial use of these products in sheet and other basic forms is anticipated. Improved welding techniques for the cupro-nickels are being developed and the general availability of cupro-nickel should be considered when special corrosion problems are encountered.

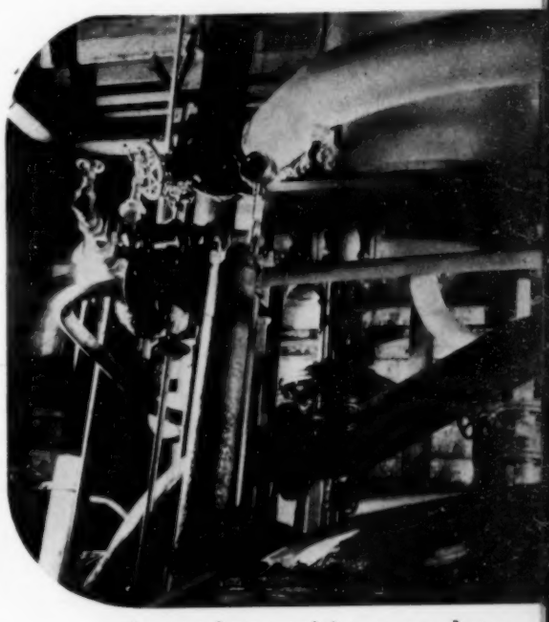
Alloys of copper and zinc, commonly known as the brasses, find extensive use in general industry, but rather limited application in the chemical industries. The alloying of zinc with copper yields a series of materials which have excellent physical properties, but which show a decreased resistance to general corrosion and particularly to acid attack. For general marine use or exposure to the elements the brasses are quite satisfactory, but where active acid attack is to be encountered, they are seldom employed. In contact with sulphides, however, brasses are more highly resistant to corrosion than copper itself and as a rough generality the resistance to sulphide attack increases with the zinc content. Muntz Metal, an alloy containing 60 per cent copper, 40 per cent zinc, is probably the most suitable of the copper base materials for use in contact with sulphides.

Tin or Phosphor Bronzes

Tin bronzes, or, as they are commonly called, the phosphor bronzes, because of the practice of using phosphorous as a deoxidant in connection with their manufacture, are of some engineering interest. They possess excellent corrosion-resisting properties, which in general are comparable to those of copper and copper-silicon alloys. However, because of the relatively high cost of the tin entering into their composition and the expensive nature of the fabricating operations necessary to the production of basic industrial forms, they are not used extensively in wrought form.

Aluminum bronzes, from the stand-

(Please turn to page 596)



A maze of copper piping conveys charge and discharge to and from a 4-story still

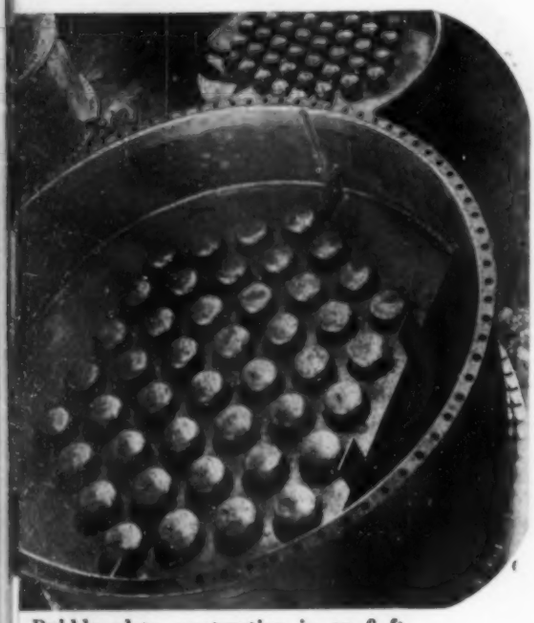
* Everdur, Herculoy, Olympic Bronze, PMG Metal and Duronze

ALUMINUM EQUIPMENT

By H. J. FAHRNEY,
Aluminum Company of America, New Kensington, Pa.

TWO PROBLEMS CONFRONT THE DESIGNER of chemical plant equipment. First of these is the selection of a material of construction which has suitable chemical characteristics and which is available at reasonable cost. Second is the preparation of designs using the selected material and providing specified performance at greatest economy. Here we shall concern ourselves with aluminum, a material resistant to the corrosive attack of many chemicals, yet low in cost and easily fabricated by ordinary methods.

Among products processed, stored or shipped in aluminum are concentrated nitric acid, glacial acetic acid, formaldehyde and sulphur compounds. The resistance of aluminum to corrosion is utilized in other instances in which a product is made corrosive to other metals by the presence of impurities. To illustrate, petroleum is made corrosive to steel by hydrogen sulphide which is present as an impurity. Therefore aluminum, which is resistant to hydrogen sulphide, is used to some extent for refinery equipment.



Bubble plate construction in an 8 ft. diameter recovery tower of aluminum

Although there are very few, if any, groups of chemically related materials all members of which are without effect upon aluminum, there are several types of compounds which are usually not corrosive. Among these are oxidizing acids such as nitric and oxidizing solutions such as hydrogen peroxide and alkali metal chlorates which attack aluminum very slowly. Sulphur compounds, with the exception of the sulphur acids, are usually without effect. Excepting the halogen compounds, aluminum resists the action of ammonium salts. Most organic compounds, with the exception of those containing chlorine or other halogens, do not attack aluminum. Among the organic substances in this category are the hydrocarbons, fatty acids, alcohols, ethers, aldehydes and ketones. Chlorinated compounds such as carbon tetrachloride or trichlorethylene are without effect unless water is present. Even in cases in which some attack on aluminum does occur it is sometimes less expensive to use aluminum, making proper allowances for corrosion losses, than more expensive materials which are completely resistant.

Of almost equal importance is the fact that aluminum has little or no effect upon the color of materials processed in it. This is because the compounds of aluminum are colorless. It is for this reason that aluminum is used in the manufacture of such materials as varnish, synthetic resins, cosmetics, titanium oxide, white mineral oils, fatty acids and other products in which clear and light colors must be maintained.

Another characteristic of aluminum is that it does not catalyze the dissociation of certain unstable compounds. That is the reason why aluminum is the only commercially available metal in which concentrated hydrogen peroxide may be stored without excessive dissociation of the peroxide. This effect is also observed in the case of ammonium nitrate which becomes unstable and subject to spontaneous detonation after contact with heavy metals. It is entirely unaffected by contact with aluminum. A somewhat similar effect is observed in the processing of mineral, vegetable and animal oils. It has been found that animal and vegetable fats and oils which have been deodorized in aluminum or subjected to other treatments which involve exposure to high temperatures, become rancid at a much lower rate than do oils and fats processed in other metals. Rancidity, of course, results from oxidation of the oil. Recent tests have also shown that mineral lubricating oils absorb oxygen and hence lose their lubricating values at a much lower rate when in contact with aluminum only, than when in contact with other metals.

Non-Toxic and Non-Sparking

Of particular importance to brewing and other fermentation industries is the fact that aluminum is nontoxic. It has no effect upon the yeast cultures used in brewing or upon other types of micro-organisms used in such fermentation processes as the manufacture of citric and gluconic acid.

Aluminum is non-sparking. It is frequently employed for equipment used in processing, mixing and packaging explosives. It is also employed in cases in which flammable vapors or liquids are exposed to metals which may be accidentally struck by hard objects.

Properties which make aluminum useful to the chemical industry are largely due to the presence of an inert film of aluminum oxide which forms instantly when aluminum is exposed to air. The service life of aluminum may frequently be extended by periodic cleaning, one purpose of which is to remove adhering matter which excludes oxygen and so retards the renewal of the protective oxide film. In many instances, cleaning with an abrasive such as steel wool will suffice.

Some of the chemical industries in which aluminum has been used to a great extent are the manufacture of glacial acetic acid, acetic anhydride, naval stores, hydrogen peroxide, rayon, citric acid, gelatine and synthetic resins. In fact, these industries now consider aluminum a standard construction material.

Fabricating Aluminum Equipment

Design and fabrication of aluminum equipment is quite similar to that of other metals. Data concerning the physical properties of aluminum and its alloys is unusually complete and accurate. With a few exceptions, the operations required in the fabrication

of aluminum may be performed with equipment used for similar operations on other metals. While the technique of the most commonly used methods for joining aluminum, gas and electric welding, differs slightly from that used on other metals, it can be readily mastered by skilled welders.

Several States now require that the design of pressure vessels be approved and inspection of the vessels be made during fabrication. The Hartford Steam Boiler Insurance Co. has established a code for the design of aluminum pressure vessels and this company's approval of the design and inspection of the vessel satisfies the legal requirements of all such States. It is, therefore, possible for the engineer to confidently take full advantage of the light weight, strength and high thermal conductivity of aluminum alloys even under severe conditions of service, such as those involving high pressure or temperatures.

Few Alloys Suitable

Although the alloys of aluminum are quite numerous, only a comparatively small number of them are ordinarily used for chemical equipment. In most cases in which aluminum is used because of its resistance to corrosion or because its compounds are colorless and when maximum strength is not required, commercially pure aluminum, known as 2S, or an alloy containing 1½ per cent of manganese, known as 3S, are used. Both have good corrosion resistance, moderate strength and can readily be fabricated by welding.

When corrosion conditions are particularly severe or when special properties, such as minimum effect upon unstable compounds or materials undergoing fermentation, are required, metal containing a minimum of 99.5 per cent aluminum is often used. While such metal is more inert to materials which are processed in it, its strength and hardness are lower than those of 2S or 3S. For this reason it is not used unless chemical conditions make it necessary.

When a high degree of corrosion resistance must be combined with physical properties superior or those of 2S or 3S, 53S alloy is frequently used. This is an alloy containing silicon, magnesium and chromium. Its use for chemical equipment is somewhat restricted by the fact that it does not weld as readily as 2S or 3S. Consequently, use of 53S is confined largely to tubing, extruded sections, forgings and designs in which a minimum of welding is required.

An alloy of aluminum, magnesium and chromium, known at 52S, has been found useful in the chemical industry, particularly when exposures to high temperatures are involved. The physical properties of this metal are developed by cold working and are much superior to those of 2S or 3S. One characteristic that makes this alloy particularly interesting to the chemical industry is that it retains more of its strength at elevated temperatures than do other aluminum alloys. It is, therefore, well adapted to equipment which operates at high temperatures, such as varnish kettles and resin stills.

Castings are frequently required for fittings and accessories. One of the most commonly used casting alloys for such parts is 43 alloy which contains 5 per cent silicon. This alloy casts well, has good physical properties and can be machined. It has excellent resistance to a variety of materials, being particularly resistant to acids. A heat treated silicon-bearing casting alloy, known as 356 alloy, is used when higher strength and better machinability are needed. Another casting allow frequently used is 214 which contains 4 per cent magnesium. It is slightly more difficult to cast than 43 alloy but can be machined with greater ease. While its resistance to acid solutions is not quite equal to that of 43 alloy, it has excellent resistance to other types of solutions, including those which are slightly alkaline or which contain chlorides.

Forms and Sizes Available

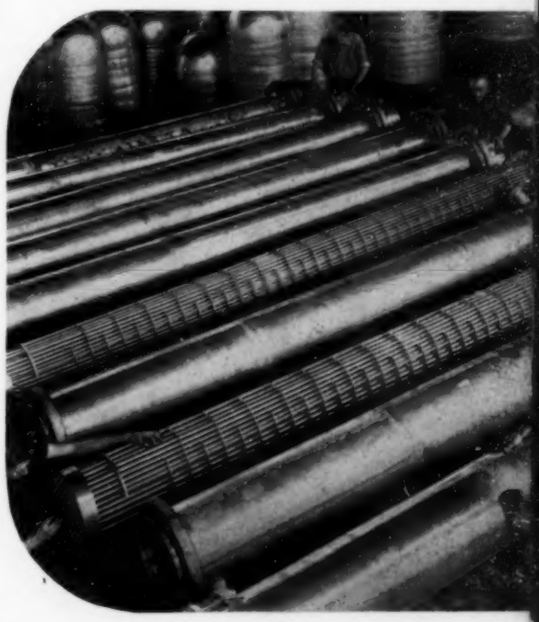
Design of aluminum equipment is facilitated by the variety and size of materials available. Sheet and plate are available in thicknesses up to 3 in. The maximum width of heavy plate is 11 ft. and the length is determined by the thickness and final weight which may be as great as 3,400 lb. Seamless drawn tubing is available in a range of outside diameters from ⅛ in. to 12 in. and in wall thicknesses from 0.010 in. to ½ in. Tubing of special cross sections, such as square, rectangular and fluted is also available. Standard structural shapes, including angles, channels, tees and others are available in sizes as large as 6 in. x 6 in. angles, 12 in. channels and 5 in. x 3 in. tees. The extrusion process makes it possible to obtain special sections in which the disposition of the metal is determined by the requirements of the design and not by fabricating limitations as in the case of rolled sections.

With the exception of welding, the fabrication of aluminum differs very little from that of other metals. Shops which specialize in aluminum are equipped to roll-form plates as wide as 14 ft. and as thick as ¾ in. Larger plates are often formed on rolls used in steel fabricating shops.

Dished heads for tanks and other equipment may be formed either by spinning or pressing. Ordinarily heads of diameters up to 96 in. are spun, while larger heads are pressed.

Most Equipment Is Welded

Practically all chemical equipment is assembled by welding. Body welds which must be entirely free from porosity, so as to be leakproof, are usually made by torch welding, using either the oxy-acetylene or oxy-hydrogen flame. When mechanical strength



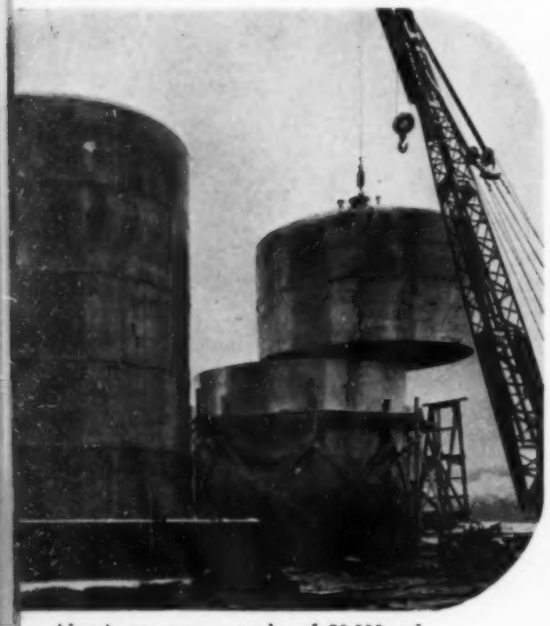
Aluminum condensers for use in removing H_2S from petroleum refinery gases

is the primary requirement, as in the attachment of brackets for structural supports, arc welding is usually employed. As far as possible, welding wire of the same composition as the base metal is used. Aluminum plates of 2S and 3S as thick as 1 in. have been welded with the torch and it is believed that even thicker plates may be welded if needed. The use of spot and seam welding is largely confined to the assembly of fittings and accessories. It is now possible to spot weld aluminum sections as thick as

⅞ in. and seam weld sections ⅛ in. thick. Spot and seam welding equipment used for steel can usually be converted to weld aluminum.

Comparatively little riveting is required in the fabrication of aluminum equipment. When needed, however, it is performed in much the same manner as the riveting of other metals. Rivets no larger than ½ in. and ⅝ in. in diameter are usually driven cold.

The ease with which aluminum may be formed facilitates the flanging of such parts as tank sections, pipe connections and manhole fittings. Such flanging is usually done by hand, and steel back-up rings are frequently used. In attaching tubes to header plates as in condensers, heat exchangers and similar apparatus, a mechanical joint is usually used. Either one or two rings are machined in the tube hole and the tube is expanded into these rings. Occasionally tubes are welded into header plates, the tube end projecting slightly beyond the tube sheet, and fillet welding used.



Aluminum storage tanks of 80,000 gal. capacity erected amid the snowbanks

Among the aluminum equipment which is regularly fabricated are tanks, heat exchangers, condensers, distillation columns, scrubbing towers, jacketed vessels, stills, evaporators, fume removal systems, dryers, tank cars and shipping containers. Much of this has been of such design and dimensions that it has been completely assembled in the fabricator's shop. Recently more of it is being assembled either completely or partially in the field. Typical of this larger equipment are storage tanks as large as 168,000 gal. capacity which are 35 ft. in diameter and 20 ft. high, scrubbing columns as high as 40 ft. and absorption towers as high as 57 ft. Ease of fabricating aluminum is demonstrated by the fact that several large tanks have been erected in the field in mid-winter. (For illustration see cut on this page.)

Just as chemical research is constantly creating new products and processes, the research program of the aluminum industry is constantly seeking to develop new alloys and better methods of fabricating them into forms useful to the chemical engineer. The ultimate effect of this research will be to provide cheaper, more durable or more convenient equipment for use in the chemical industry.

COPPER CONSTRUCTION

(Continued from page 593)

point of corrosion, are characterized by excellent resistance to the corrosive attack of acid solutions, and in this respect not only are generally superior to the brasses but, under some conditions, superior to copper and the copper-silicon alloys. They possess high strength and excellent physical properties. Ordinarily, the amount of aluminum in the commercial wrought form does not exceed 10 per cent.

In general, the application of wrought aluminum bronzes in the construction of corrosion-resisting equipment is limited by two factors. The first is that wrought forms of these alloys present manufacturing difficulties which tend to increase their cost, and the second is, that no satisfactory welding technique has been developed for these alloys.

Tin bronzes and aluminum bronzes are available in sheet, rod and strip, but their largest application is in the form of castings. While ordinary phosphor bronzes and aluminum bronzes are used extensively in the manufacture of acid-resisting castings, it is common practice to modify the aluminum bronzes by the addition of iron or nickel and the tin bronzes by the addition of lead and sometimes zinc.

In general, when a casting of corrosion-resisting copper alloy is desired, the selection of the specific casting mixture depends largely upon the duty which the casting is to perform. Where high strength is required in combination with corrosion resistance, the aluminum bronzes find favor.

As a matter of general interest, a tabular listing of a few typical uses of cast copper-base alloys in the manufacture of chemical equipment may be found below. This table by no means covers the full range of use of copper alloys in the chemical industries and therefore should not be used as a guide except in combination with full knowledge of operating conditions.

Typical Uses of Copper Alloys

Agent	Parts	Class of Alloy
	Bronzes	
Hydrochloric acid (dilute)	Pumps, air lifts	Al. and phosphor bronzes
Sulphuric acid (6%)	Pickling tank equip.	Aluminum bronzes
Dilute (below 75%)	Pumps	Aluminum bronzes
Cold and hot below 50%	Storage	Silicon bronzes
Sulphurous acid	Pumps	Aluminum bronzes
Alums	Pumps	Leaded bronze
Aluminum sulphate	Pumps	Leaded bronze
Copper nitrate	Pumps	Bronze
Copper sulphate	Pumps	Aluminum bronze
Ferrous sulphate	Filters	Bronze
Potassium chloride	Pumps	Bronze, aluminum bronze
Sodium chloride	Pumps, piping	Naval brass
Sodium sulphate	Pumps	Bronze
Zinc chloride	Evaporators	Silicon bronze
Zinc nitrate	Pumps	60-38-2 Cu, Zn, Sn bronze
Zinc sulphate	Pumps	Bronze, aluminum bronze
Potassium hydroxide	Storage	Aluminum bronze
Oxygen	Valves	Bronze
Sulphur dioxide	Fans	Bronze, aluminum bronze
Sulphur dioxide (moist gas) below 300° F.	Piping	Aluminum bronze
Sulphite liquor	Pumps, valves	Bronze
Acetic acid	Filters, piping	Bronze, aluminum bronze
Acetic acid (glacial)	Pumps, piping	Aluminum bronze
Fatty acids	Condensers, pumps	Aluminum bronze
Gallic acid	Pumps	Bronze
Lactic acid	Pumps	Bronze
Salicylic acid	Pumps	Bronze
Alcohols	Pumps	Bronze
	Brasses	
Alums	Piping	Brass
Sodium chloride	Condenser tubes	Admiralty brass
Sludge acid (dilute)	Pipe	Brass
Fatty acids (dilute)	Pumps	Brass
Glycerine	Condenser tubes	Admiralty

NICKEL AND ITS ALLOYS

By W. F. BURCHFIELD and F. G. FLOCKE
International Nickel Co., Inc., New York, N. Y.

AN ENGINEER INTERESTED IN THE DESIGN of chemical engineering equipment to be made of nickel or either of the high-nickel alloys, Monel[1] and Inconel can safely proceed on the assumption that any design which is practical in steel can be duplicated with these nickel alloys. Likewise fabricating methods—riveting, welding, annealing, hot and cold working—are more like those used with steel than those commonly employed with the other non-ferrous materials such as copper. Nevertheless, it is true that capable coppersmiths, as well as steel fabricators, are able to turn out satisfactory equipment using the high-nickel materials.

In designing pressure and vacuum vessels in Monel, nickel and Inconel[1] the adopted formulas of the A.S.M.E. and the A.P.I.-A.S.M.E. Codes for Unfired Pressure Vessels are used. Judgment is necessary in taking advantage of the higher physical values of these materials as compared with mild steel in cases where the indicated thickness falls below ⅛ in., since the rigidity of the structure may be the determining factor in vessels of light gage construction.

For structures that need not meet the requirements of the Unfired Pressure Vessel Code, the following minimum tensile strength values may be used in computing the safe working stresses for calculating purposes.

The tensile strength values cited in Table I for standard cold rolled sheet are for soft annealed material. Higher properties are obtainable in special cold rolled sheet and strip which are produced in nine tempers, from dead soft to full hard.

In determining safe working stresses for the calculation of the metal thickness for vessels that need not meet Code requirements, it is safe to use lower factors of safety than are generally desired in the design of carbon steel vessels, since these ordinarily include some allowance for rust or other types of corrosion. The following safety factors, which do not include provision for corrosion, are suggested: 3.5 for shells ½ in. thick and over, 4 for shells under ½ in. to ⅜ in. thick, and 5 for shells under ⅜ in. thick.

Practical fabricating considerations and probable loss in rigidity account for the larger factors for the thinner gage material. To the calculated thickness as determined by using these safety factors, should be added such additional thickness as is estimated will be required to provide for corrosion losses over the expected life of the vessel.

Safe working stresses at room temperature may be used in the design of heavy equipment in Monel to operate at temperatures up to 700 deg. F. With Inconel this temperature limit may be extended to 850 deg. F. In the case of nickel, 500 deg. F. has been set tentatively as the upper limit for the proper use of room temperature strength for design purposes.

Table II cites shearing and crushing strengths which may be used in the design of riveted joints. These values were derived from actual tests on riveted joints.

The following joint efficiency factors may be used for metallic arc welded joints, except where lower values must be used on account of Code requirements.

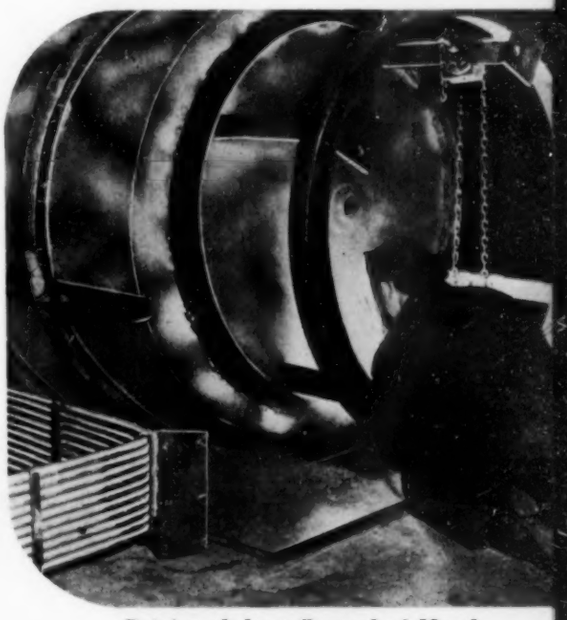
Type of Joint	Joint Efficiency Factor
Double butt welded joint	.90
Single welded butt joint with backing-up strip	.90
Single welded butt joint, without backing-up strip	.80
Double full-fillet lap joint	.70
Single full-fillet lap joint, with plug welds	.70
Single full-fillet lap joint	.60

Table I—Tensile Strength of Sheets, Plates and Tubing

Material	Minimum Tensile Strength p.s.i.
Monel	
Standard cold rolled sheet	65,000
Hot rolled plate, annealed	70,000
Hot rolled plate as rolled	80,000
Cold drawn tubing, annealed	70,000
Cold drawn tubing, as drawn	90,000
Nickel	
Standard cold rolled sheet	60,000
Hot rolled plate, annealed	65,000
Hot rolled plate, as rolled	70,000
Cold drawn tubing, annealed	60,000
Cold drawn tubing, as drawn	80,000
Inconel	
Standard cold rolled sheet	80,000
Hot rolled plate, annealed	85,000
Hot rolled plate, as rolled	95,000
Cold drawn tubing, annealed	80,000
Cold drawn tubing, as drawn	110,000

Table II—Shearing and Crushing Strength for Design of Riveted Joints

	Nickel	Monel	Inconel
Tensile strength of plate, p.s.i.	70,000	75,000	80,000
Shearing strength of rivet in single shear, p.s.i.	.....	50,000	55,000
Shearing strength of rivet in double shear, p.s.i.	.....	100,000	110,000
Crushing strength of plate, p.s.i.	100,000	105,000	115,000



Reinforced dyestuff vessel of Monel, 5 ft. in diameter and 5 ft. in depth

Tests on Monel, nickel and Inconel at temperatures considerably below zero show that values for their tensile strength and yield strength increase at least 40 per cent as the temperature is lowered from room temperature to that of liquid air. Of more interest to the designer is the fact that these metals maintain their room temperature ductility and impact values at these very low temperatures.

Fabricated vessels of Monel, nickel and Inconel need not be stress relieved in order to insure safety of the

[1]Of the high-nickel alloys, only Monel (containing approximately two thirds nickel and one third copper), rolled nickel and Inconel (containing approximately 80 per cent nickel with additions of chromium and iron), come within the direct scope of this article. Reference should be made, however, to certain modifications of Monel and nickel such as "R" Monel, especially suited for automatic machining operations, "K" Monel, a precipitation hardening alloy of high strength with non-magnetic qualities, and "Z" nickel, a precipitation alloy having high strength, good magnetic permeability and relatively good electrical conductivity. Complete data on the chemical composition and physical constants of these and other nickel alloys will be found in the Data Sheet section of this issue of **Chem. & Met.** See especially p. 636.

structure. Of course, stress relief treatment must be undertaken to meet Code requirements, although proper thermal treatment for stress distribution of high nickel materials does equalize stresses and definitely increases the proportional limit without lowering the hardness of the material. If thermal stress distribution treatment is required by Code, the same practice as is prescribed by the A.S.M.E. Boiler Code for carbon steel vessels is applicable to Monel, nickel and Inconel vessels. A minimum temperature of 1100 deg. F. should be maintained for one hour for each inch of thickness. The maximum for these materials should not exceed 1200 deg. F. for nickel, 1250 deg. F. for Monel, and 1300 deg. F. for Inconel.

The high nickel materials do not require heat treatment after welding, nor surface polishing or chemical passivating treatment after severe cold work to restore their corrosion resistance.

Interior of a pure-nickel-lined hold in unique tank steamer, "Dolomite 4"

Choice of Joining Methods

The choice of the joining method depends upon the use to which the equipment is to be subjected and specifically involves questions of corrosion and operating temperatures. Those methods commonly used for steel are regularly used for joining the high nickel alloys and include soft or silver soldering, or any available fusion or resistance welding methods.

RIVETING—Monel, nickel and Inconel rivets are available in any standard size and shape of head. Good riveting practice dictates that holes be punched undersized, then reamed to size. Rivets $\frac{7}{8}$ in. diameter and smaller can be driven cold, whereas rivets larger than $\frac{7}{8}$ in. diameter are driven hot, with rivets heated to 1950 deg. to 2100 deg. F. (yellow to light yellow) in Monel, nickel and Inconel.

WELDING—The choice of the welding method will depend upon the design of the job rather on the metal being welded. The production of sound ductile welds free from blow holes, porosity and cracks will follow adherence to proper procedure. All wrought forms and well made castings of Monel, nickel and Inconel are weldable.

METAL ARC WELDING—Heavy equipment built of thick sheet or plate is usually welded with the metal arc, for which shielded arc electrodes are available in the three materials. This welding process can be used for welding sheet as thin as .050 in. (18 ga. U.S.S.) with satisfactory results, but still thinner material can be arc welded in special cases if particular attention is paid to fitting and clamping the joints. The range of electrode diameters available includes the usual sizes from $\frac{1}{16}$ in. through $\frac{1}{4}$ in. in Monel, and $\frac{3}{32}$ in. to $\frac{1}{8}$ in. in nickel and Inconel. A 75 deg. bevel is required for butt joints in plates $\frac{1}{8}$ in. and heavier. Below this thickness the joint is set up with square sheared edges.

Reversed Polarity Required

Monel, nickel and Inconel electrodes, all carrying relatively thick flux coatings, require reversed polarity. These welding rods flow freely with correct adjustment of the welding machine, giving a bead that shows no porosity or cracking. Complete penetration is possible in welding sheet up to 10 gage with a single bead, either with or without a suitable backing-up, and without veeing.

The angle of the electrode in making butt welds should be from the vertical position to about 30 deg. from the vertical. Actually, the electrode should be about normal to the molten pool of weld metal. In fillet welds, where metal thicknesses are the same, a 45 deg. electrode position, bisecting the fillet, is good practice.

For horizontal, vertical, or overhead welding, practices regularly followed in steel welding are followed. Using identical gages in either Monel, nickel or steel, and identical set-ups and welding processes, will give essentially the same results as to the degree of buckling.

Jigs Are a Valuable Aid

Jigs and clamping devices are unquestionably a valuable aid in most welding jobs and their use is recommended. On fillet welds, where it is convenient, and certainly on thin materials, it is desirable that an angle be used to back up a joint.

Physical Properties of Metal Arc Welds

	Tensile Strength p.s.i.	Per Cent Elongation In Free Bend
Monel....	70,000 min. to 85,000	30 min.
Nickel....	60,000 min. to 70,000	30 min.
Inconel...	80,000 min.	

The nickel and high nickel alloy electrodes have been designed so that, when used under normal operating conditions, the deposited weld metal will have tensile and corrosion resisting properties equal to or superior to the properties of the parent metal.

DISSIMILAR METALS—It often becomes necessary to join dissimilar metals, such as Monel to steel, and nickel to steel. A procedure which has been used successfully for a number of years in welding Monel sheet and plate to medium carbon steels has been to use the coated Monel electrode. The physical properties obtained in joints between carbon steel and Monel when welded with Monel electrodes are given in the following table:

Physical Properties of Arc Welds Between Monel and Steel, Welds Made with Monel Electrodes

	Tensile Strength, p.s.i.	Ductility Free Bend, Per Cent	Remarks
Reduced Section Tensile.....	64,851	.....	Break in Steel
Full Section Tensile.....	61,871	.....	Break in Steel
Free Bend Test.	.....	41.83	No Failure
Nick Break Test	.....	.....	O.K., Fine Grain, No Defects.

Tensile values of the same order were obtained in joints in which both Monel and steel plates were $\frac{3}{4}$ in. thick.

When joining nickel to steel, a Monel electrode is again used. For example, in welding a nickel pipe connection into a nickel-clad steel vessel, the outside fillet is between the nickel pipe surface and the steel side of the nickel-clad steel. This joint is easily made using a Monel electrode, but is not successful with either a steel or nickel electrode. Strong joints can likewise be made between Inconel and steel through the use of

the coated Inconel metal electrodes.

OXY-ACETYLENE WELDING—This method is being used for sheet metal work for the joining of very thin sheet 0.021 in. up to about ⅛ in., and is not often used for sheets thicker than ⅛ in. except in special instances. Because of the somewhat lower rate of heat input, oxy-acetylene welding is particularly applicable to the joining of tubing smaller than 3 in. diameter and with wall thicknesses less than about ⅛ in. or 3/32 in. Gas welding rods are available in all three materials from 1/16 in. to 3/16 in. diameter. Suitable fluxes are used with Monel and Inconel, but none is required for nickel.

Gas Welding of Nickel

The gas welding of Monel, nickel and Inconel is easily done. After painting the flux on both sides of the joint, then adjusting the flame to slightly reducing conditions and after beginning to weld, the welder will notice that Monel and Inconel flow freely. Nickel, which is not fluxed, flows a little sluggishly. The appearance of properly made gas welds is quite similar to that of a good steel weld.

The proper size of tip is best determined by the welder's experience, although as basic practice the same size or one size larger than that recommended by the torch manufacturers for similar gage steel, may be used.

The oxy-acetylene flame used should be very slightly reducing, that is, there should be a little excess acetylene with only a slight feather no longer than an eighth of an inch showing beyond the tip of the luminous cone. In the case of nickel and Inconel, definitely oxidized metal results if a reducing flame is not used. Besides being reducing, the flame should be soft, rather than harsh, as is the case when too small a tip is used.

SILVER BRAZING—Silver solders and high temperature brazing metals can be used satisfactorily for joining Monel nickel and Inconel if corrosion conditions permit their use. Silver solders having melting points within the range of 1175 deg. F. to 1325 deg. F. are preferred for these materials.[1] Sheet or flow must be heated only enough to flow out the silver solder or the brazing rod. A small oxy-acetylene torch with very small tip works very well with silver soldering. The flame should be kept moving. Flux should be painted on the edges to be joined to improve the flow of the solder and to avoid discoloration.

SOFT SOLDERING—Soft soldering is a convenient, easy means of joining where corrosion and contamination are not troublesome and where strength is not required. Soft solder is inherently weak and must not be used where finished equipment will be subjected to vibration or high stresses. Before lock seaming or joining, the edges of the sheet should be tinned, preferably with an iron rather than with a torch. After joining and seaming, the solder can be sweated through very easily. When the work is clean, especially when cleaned finally with emery cloth, any of the regular zinc chloride base fluxes, such as are made by neutralizing muriatic acid with zinc, will work satisfactorily. With Inconel it may be necessary to add a little uncut acid to make the cleaning action a little more vigorous. Oxide and furnace scale must be ground off or removed with emery cloth before tinning.

RESISTANCE WELDING—Regular standard spot welding machines now on the market are suitable for Monel, nickel and Inconel. A number of standard and custom-built seam welding machines also give satisfactory results. Three factors require adjustment on spot welders: pressure, current and time. When spot welding, the pressure between electrodes should be lighter than is used ordinarily on steel, the current should be higher, and the time should be shorter. A properly adjusted machine will produce sound, uniform spot welds. The metal should not be overheated by leaving current on too long. The metal, of course, must be clean and free from oil or other foreign materials. Seam welding is being used on gages 0.109 in. and lighter.

These materials can be spot welded to practically all other commonly used materials of construction, except aluminum, lead and zinc.

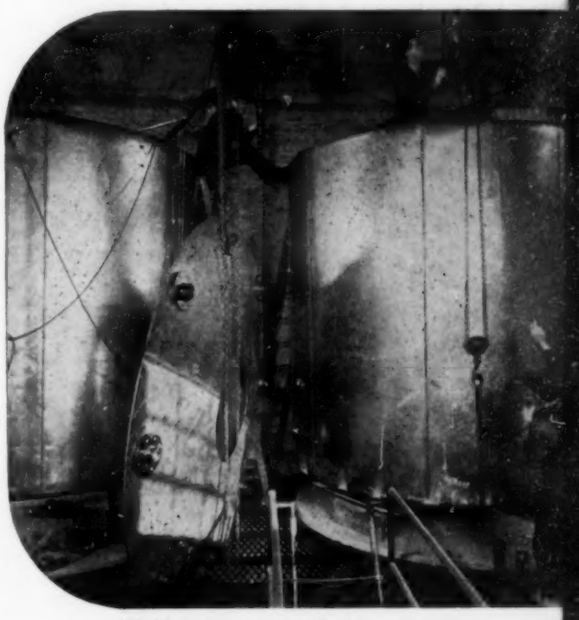
Hot Working

Before being exposed to high temperatures, these materials should be cleaned thoroughly to remove oil, paint marks and adherent substances which may contain sulphur, lead or other harmful ingredients.

The length of heating is also very important, and the work should be arranged so that material is charged into the furnace at regular intervals and will have only sufficient time to be heated throughout to the desired temperature before being withdrawn for working. If operations should be stopped for any reason, material should be withdrawn from the furnace, to be recharged when work is resumed. Under no conditions should these materials be allowed to "soak" in the furnace, particularly if several reheatings are to be required in the course of the work, because "soaking" has been found to be definitely harmful.

Sulphur Attacks Surface

Monel, nickel and Inconel develop a peculiar intercrystalline attack when exposed to the action of sulphur-bearing compounds at high temperatures. Also, a strongly oxidizing atmosphere, even in the absence of sulphur, may produce undesirable surface attack especially on Monel and nickel. Consequently, the most satisfactory furnace atmosphere condition for properly heating these high nickel materials is a sulphur-free reducing atmosphere.



Welded Inconel tank for storage of alcoholic spirits and strong gin

There is one case where an oxidizing atmosphere may have an advantage over a reducing condition, and that is when the heating medium may contain over 0.5 per cent sulphur. Under this condition, the oxide film which quickly forms on the metal protects it from sulphur attack.

The time required to heat these

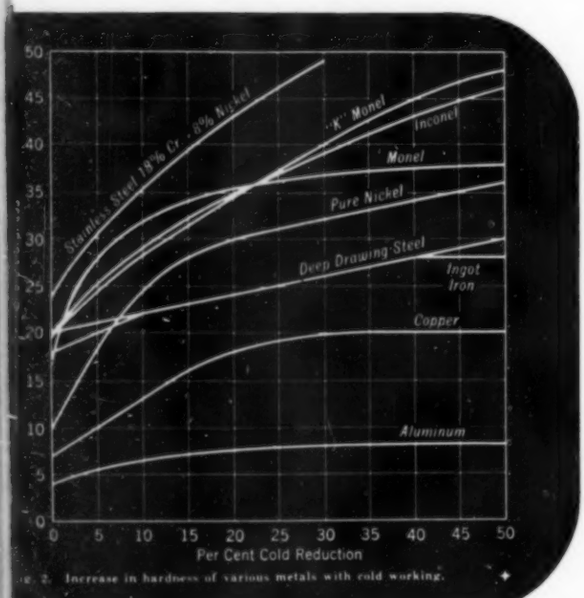
[1] Easy Flo Brazing Alloy, Grade RT solder and Handy Flux, made by Handy and Harman, New York City, are recommended.

metals varies widely with furnace efficiency and weight of charge, but on an average it takes from 15 to 20 min. per in. of thickness for Monel, 10 to 15 min. per in. of thickness for nickel, and 20 to 30 min. per in. of thickness for Inconel.

Furnaces should be designed so as to provide ample space for combustion of the fuel before the hot gases reach the materials. It is also important to keep the charge clear of the furnace floor, provide ample circulation of the products of combustion so as to maintain uniform temperatures throughout, and maintain reasonable air-tightness so as to assist in maintaining the desired atmosphere.

Forging Requires Much Power

FORGING—These materials (with the exception of "R" Monel, which is not recommended for hot forming)



Increase in hardness of various metals with cold working.

Increase in hardness of various metals produced by cold working

can be forged into any shape regularly produced in steel, although their high strength at forging temperatures may require increased power. A chart presented on page 614 of this issue shows the recommended working temperature ranges. These limits should be adhered to as closely as possible.

In order to develop the best physical properties in hot worked products, forging should be stopped when the piece is nearly to the desired size and shape. The material should be allowed to cool to 1200 deg. F. (barely visible red color), and the work then finished by semi-cold work below this temperature.

Annealing Nickel Alloys

The important factors in annealing these high nickel alloys are: (a) close control of the time of annealing at temperatures above 1350 deg. F. for nickel, 1450 deg. F. for Monel and 1750 deg. F. for Inconel. Above these temperatures rapid grain growth takes place. (b) protection of metal against embrittlement and excessive oxidation by providing low-sulphur, non-scaling heating atmospheres, and (c) use of furnaces that permit complete combustion before the hot gases strike the metal.

Electric heating is ideal when means are provided to exclude oxygen by admitting gas or a low volatile hydrocarbon fuel, such as propane.

The furnace should be brought to the required temperature before charging the work. The burners may be adjusted to give the best combustion for bringing the furnace up to steady temperature, and before charging, the air supply should be reduced to give the excess of combustible gases required for clean heating. The top vents or dampers should be wholly or partially closed to give a positive gas pressure over the hearth to prevent the entrance of air.

The following temperatures and times may be used:

	Temp. Deg. F.	Time at Temperature in Minutes: Drawn Shapes	Time at Temperature in Minutes: Spinnings
Inconel.....	1800	10 to 15	15 to 20
	1950	½ to 2	3 to 5
Monel.....	1600	2 to 5	5 to 10
	1800	½ to 2	3 to 5
Nickel.....	1500	2 to 5	5 to 10
	1700	½ to 2	3 to 5

The above times at temperature include a sufficiently wide range to provide a satisfactory latitude in handling the work in and out of the furnace. The shorter time given does not yield full softness, but does condition the metal for operations such as cupping, drawing, stamping, and the like. In general, the more cold work a metal has the faster it will recover full ductility at given temperatures.

Quenching in Alcohol

Monel and nickel may be quenched in a 2 per cent alcohol solution (1 gal. methanol or denatured alcohol to 50 gal. of water) to reduce the oxide flash formed in drawing the pieces out

(*Please turn to page 614*)

TANTALUM

TANTALUM IS INERT to chlorine, bromine, iodine and most of their compounds, as well as to practically all other corrosive chemicals except the alkalis, free SO_3, hydrofluoric acid, and ammonia at high temperatures and pressures. It is slowly attacked by concentrated phosphoric acid at boiling temperatures.

Tantalum is an excellent material for heat transfer equipment such as heating and cooling coils, condensers, evaporators, and absorbers. Although its thermal conductivity is about that of steel, extremely high overall coefficients are obtainable because of its corrosion resistance which prevents formation of scale and permits the use of very thin sections. Furthermore, liquids wet tantalum more readily than other metals.

The unannealed metal has a strength comparable to cold rolled steel, while in the annealed condition it may be compared to annealed steel. It welds easily to itself and certain other metals by electric spot, butt, seam and roller processes. It may be arc welded to itself, but the process is difficult and is accomplished only by a special method practiced in the fabricating plant of the Fansteel Metallurgical Corporation. Resistance to wear can be greatly improved by hardening, and this is commonly done when tantalum equipment is subject to abrasion as well as corrosion.

Experience in the stamping, welding, drawing, forming and working of the metal makes it possible now to supply practically any form of tantalum equipment.

One of the customary procedures is to take some standard piece of equipment such as a valve and line it with a homogenous lining of tantalum or to line steel, brass or copper pipe with tantalum. Smaller tubes are often made entirely of the metal.

One of the newer applications for tantalum is in the Fansteel absorption system, a complete unit of equipment, developed by the company for the purpose of producing hydrochloric acid. The first of these systems was installed in November, 1937.

An extremely hard alloy, known as Tantaloy, is non-machinable and available only in simple shapes, slabs, bars and rods for application to base metals by means of the acetylene torch. Its principal application in the chemical industries is for spray nozzles and wear resisting surfaces.

SILVER FOR PLANT USE

By A. J. DORNBLATT
American Silver Producers' Research Project

CHEMICAL INERTNESS OF SILVER to both alkalis and many acids accords it a place in the noble metals group; yet its present market price of $6.25 per lb. places it in a class with quality base metal alloys. Principal advantages are: the protective nature of its corrosion films (especially the chloride), high thermal conductivity (better heat transfer), colorlessness of silver compounds, good workability and extremely high scrap value. Silver alloys and clad silver are also becoming increasingly important.

Silver is resistant to alkalis, to organic acids, to certain concentrations of hydrochloric and other mineral acids. Its resistance to corrosion is not dependent upon a protective oxide film and silver may be used where such a film would be destroyed. Freedom from color of most organic silver salts avoids objectionable discoloration of chemical products where traces of the metal may dissolve, in contrast to what may happen in the presence of traces of nickel, iron and copper. Excepting its far more costly companion noble metals such as gold and platinum, silver is probably the most universally corrosion-resistant material at the disposition of the chemical engineer. However, even it is not resistant to many corroding agents and due care must be exercised in its application; elsewhere (Data Sheet section, page 637) a list of corroding agents is given, along with indication as to whether or not silver has been found suitable for an installation.

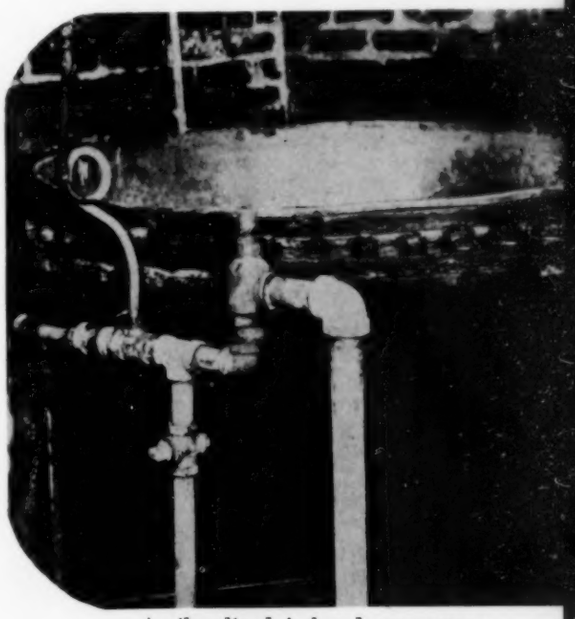
The high thermal conductivity of silver permits design of smaller heat-transfer equipment than could be constructed in any other material and also tends to shorten the operating cycle and reduce B.t.u. costs; coupled with the resistance of silver to attack by alkalis, the superior heat-transfer attainable in silver equipment gives it a decided advantage as compared with glass-lined equipment. In a particular instance a single silver batch-type reaction-kettle and still unit reduced the operating cycle to such an extent that this unit produced as much product as could have been produced by two glass-lined units in the same time; it not only occupied half as much floor-space and required less steam, but the shorter time of operation gave a product less contaminated by degradation products which form at elevated temperature. The ability to more rapidly heat and more rapidly cool beverage syrups justified the greater expense of silver compared with glass for a pasteurizing unit in which any delay in cooling from the pasteurizing temperature would impair the flavor of the product.

In regard to the initial cost of silver apparatus, it is estimated that from 50 to 75 per cent of the initial cost of solid silver equipment will be recoverable as scrap silver value, and it is sound bookkeeping to make a corresponding allowance when comparing the cost of silver equipment with that of equipment constructed of a competitive metal which has a comparatively negligible reclamation value. The corrosion-resistance of silver may in many instances be obtained at less cost and with better mechanical properties by resorting to silver coatings on a base metal, the coatings being either of the electrolytic or clad-metal type according to specific conditions. This matter is discussed somewhat more fully below in connection with comments regarding the forms in which silver is available.

High-Purity Silver Used Most

Generally the silver used in chemical equipment construction is the 99.9 per cent grade designated "fine silver" which contains less than 0.1 per cent of other elements, the chief "impurity" being copper. The silver is of still higher purity if it happens to be electrolytically deposited. With the exception of a few special alloys which cannot be discussed adequately and therefore are not included here, the maximum resistance to corrosion is attained in high purity silver. Such alloys as sterling and coin silver containing 7.5 and 10 per cent copper respectively, while mechanically superior to fine silver are inferior in corrosion resistance and entirely unsuited for many applications where fine or electroplated silver would be satisfactory. If fine silver does not possess the necessary strength, consideration should then be given to electroplating on a base metal of requisite strength, or to fabricating the apparatus of silver-clad or doublé metal.

This type of metal is quite similar to nickel-clad steel; that is, a layer of silver is bonded to and rolled down with an underlying slab of steel or other basis metal. The result is a sheet or plate with silver on one side, integrally bonded to the backing which may be of steel, copper, nickel, brass or stainless steel, as desired. Old Sheffield plate, and silver-clad metal for electrical contacts are well known, but only in the past several years have silver-clad steel and nickel come to be applied in the chemical industries. This is in part because of the fact that although the desirability of such material has long been evident, only recently have commercial problems regarding the manufacture of large sizes and methods of welding been solved. Silver-clad steel can now be fabricated by drawing, flanging, riveting or welding.



A silver-lined jacketed evaporator pan resists corrosion of chemicals

Fine silver is available in the form of sheet, plate, tubing, rod, wire, foil and powder. It finds some use as castings and as wire gauze. Silver is essentially a soft metal and may be readily fabricated into desired shapes. It possesses good machinability and can be welded. Sheets 5 ft. in width

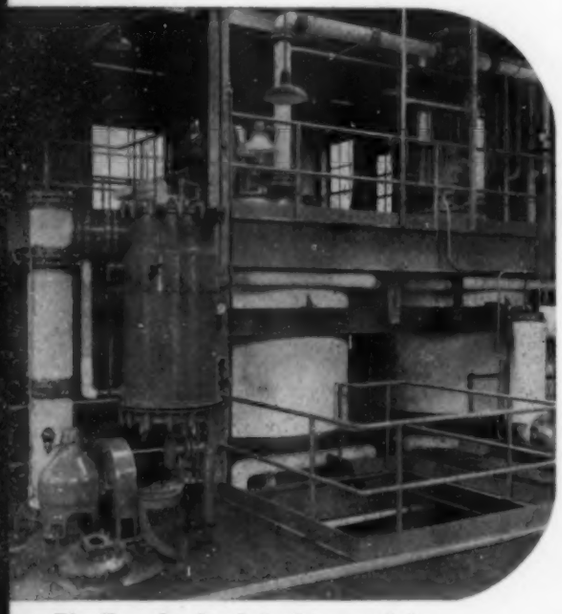
(*Please turn to page 608*)

GLASS-LINED AND SILICA

EDITORIAL STAFF

IN MANY operations the demand that the product be essentially free from contamination is such that few materials of construction will suffice. In others, so severe is the corrosiveness of the reactants that not many construction materials will exhibit the requisite life. Such cases are often solved with one of the glassy or ceramic construction materials, glass-lined steel or cast iron, fused silica or quartz, industrial glass, or chemical stoneware. A few of the characteristics and limitations of the first two classes are discussed below.

Both glass-lined and fused silica (and quartz) equipment are made only by specialists in these materials, and not by fabricators as is most equipment. Particularly in the case of glass-lined equipment, the manufacturers require complete information regarding the conditions to be met. However, the trend indicates wider and wider ranges of service for a given enamel.



Pfaudler glass-lined hook-up used by Nubian Paint & Varnish Co., Chicago

As furnished by the Pfaudler Co., glass linings are essentially complex borosilicates which are compounded, fused at high temperature and reduced to frit prior to their application to steel or cast iron. The enamels so produced are then applied by either a wet or a dry process. In the first of these the previously sand-blasted metal is sprayed before entering the furnace, then fired at a temperature of approximately 1,850 deg. F. so as to melt and fuse the powdered enamel and bond it chemically to the surface of contact. One or more finish coats are added by the same method. The wet process is suitable for use with both open and closed units.

The dry process differs in that hot dust enamels are applied to steel or cast iron equipment immediately after it is removed from the furnace, on which account the method is limited to open pieces or those to be supplied with bolted or clamped covers. Hot dust enamels are usually (but not always) specified for the more severe conditions, especially for strong mineral acids, while the wet process enamels are generally used for less severe conditions.

Substantial improvement has been effected in enamels, both in corrosion resistance and in their physical properties. Present-day enamels are considerably more flexible, for instance, although accidents do occasionally occur. For such cases a ceramic repair material has been developed, which is capable of producing a satisfactory patch.

Many types of glass-lined equipment are now made in standard types and to an increasing extent complete hook-ups of this equipment are being used for entire processes such as chlorination, sulphonation and nitration. Among the types produced by the Pfaudler Co., for example, are glass-lined valves, pipe and fittings, steel autoclaves for pressures as high as 1,000 lb., storage tanks and closed, jacketed vessels with or without agitators and other accessories, which are normally stocked in sizes from 2 to 1,000 gal. Among the newer uses for glass-lined equipment may be mentioned the large and comparatively recent one in the manufacture of vinyl and alkyd resins, where absence of dissolved metals and the maintenance of clarity are essential.

Fused Silica and Quartz

Fused (vitreous) silica and quartz are equal in chemical resistance, but are distinguished by their degree of transparency, by the materials from which they are made and by their mechanical strength. Except where transparency is needed the cheaper, opaque fused silica, which is made from a high grade of glass sand, is generally satisfactory. For special purposes demanding transparency, such as sight glasses and tubes or the application of ultra-violet light, the more expensive material produced by the fusion of rock quartz is required. Both products are generally similar in physical properties apart from the exceptions noted. Both consist of equally pure silica (about 99.8 per cent) but the fused quartz is stronger than fused silica in the tensile strength ratio of 1,700 to 6,000, as shown by the tabulation in the Data Sheet section, page 656. The transparent ware is also somewhat more resistant to crystallization at the upper temperature limit of 1,000–1,100 deg. C. Both are characterized by low thermal expansion and high resistance to sudden thermal shocks.

Opaque equipment has been produced in pieces up to 150 gal. capacity, but a 50-gal. vessel may be considered the largest practical size at the present time. Drawn tubes are obtainable in all sizes up to 4½ in. internal diameter and lengths to 10 ft., while molded pipes are made in sizes from 2 to 18 in. internal diameter, with lengths to 10 ft. for not over 9 in. bore and lesser lengths for larger bores. S-bends, elbows and connecting pieces are made to fit such tubes and pipes. Tubes are produced by drawing from a larger diameter, while pipes are made by expanding from a smaller diameter in a temperature-resisting mold. Although the drawn material is usually considered more resistant to severe temperature changes, improvements in the molded product have made it equally suitable for severe service in many cases.

Among the important uses for fused silica, burners, combustion furnaces, S-bend coolers and absorption vessels for HCl gas and muriatic acid should be mentioned. Impermeability, freedom from iron, resistance to temperature shock, and inertness to HCl have made fused silica practically standard in this field.

INDUSTRIAL GLASS

By W. A. KATES

Manager, Industrial Division, Corning Glass Works, Corning, N. Y.

A HIGH GRADE of resistance to practically all corrosive agents except hydrofluoric acid (and the caustic alkalis under some circumstances), combined with ease of fabrication into almost any desired form, long ago made glass the pre-eminent material for laboratory apparatus. For many years it has also had extensive plant use for hydrochloric acid tubing. But it is only in recent years that stills, absorbers and columns, valves, pumps, industrial piping and fittings, heat exchangers, filter blankets and a variety of other industrial glass equipment have been available for plant use.

The adaptability of industrial glassware and its future in the chemical industry are best illustrated by a brief review of the variety of forms in which it is at present utilized. Prior to such a review, however, it is of interest to outline some of the principal characteristics of available fabrication processes as they provide a useful basis for the preliminary consideration of glass parts by the practical plant engineer.

The method of manufacture of a given glass object is determined by the shape of that part, the dimensional accuracy required and the number which are to be made. Glass may be considered essentially as a high temperature thermo-plastic with the advantages and limitations implied. It may be blown into hollow and generally cylindrical, spherical or similar shapes having walls relatively thin when compared to overall dimensions. Parts cupped in shape or having a portion of general cup shape may be formed in molds, the viscous glass being dropped in the cup and pressed into shape by means of a plunger.

If the shape does not include a cavity, the molten glass may be extruded into a mold from a reservoir by air or plunger pressure. Casting by pouring is practical although little used, because of the relatively slow production rate and the large number of molds required. Tubing is produced by several methods of drawing, details of the method varying with the type of glass and the size and type of tubing. Fusing—corresponding to metal welding—is also feasible and permits similar custom tailoring of parts. Heat treating or tempering may be used to produce a substantial increase in mechanical strength. In every instance, however, the cost of tempering must be weighed against obtaining additional strength by means of additional material. In small quantities and for irregular shapes, the latter alternative is frequently preferable. Fillets, well placed chamfers, or ribs involve little or no additional cost and are generally more desirable from a glass fabrication viewpoint.

Heating, cooling, or conveying of corrosive liquids are all economically accomplished in glass piping and tubing. Diameters of the former up to 4 in. and the latter to 6 in. are now commercially available and there seem at present no technical limitations to the production of substantially larger diameters when these are warranted by demands.

The overall size of glass heat exchanger equipment is not expressed by a comparison of thermal conductivities of glass and other materials used for heat transfer. Film coefficients constitute the major thermal impedances to heat flow and are common to exchangers of all materials. As a result, therefore, glass heat exchangers compare quite favorably with those of other materials having much greater thermal conductivity. And because of chemical stability and durability, corrosion is minimized with consequent low cost per pound of liquid handled.

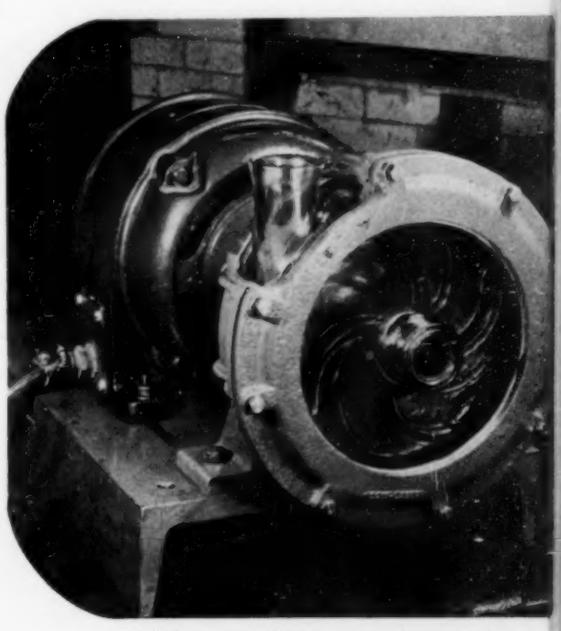
Glass For Filters

Now in the advanced test installation stage are fibrous glass filters for liquids and gases. Conventional filter cloths and bag shapes are woven from glass fiber 0.00015–0.0005 in. in diameter and are being proven in service in standard or slightly modified filter equipment.

Thermal insulation is also provided by fibrous glass in bulk or blanket form. It is completely non-hygroscopic and unaffected by acid fumes. Density of packing determines heat transmission, the conductivity at 1.5 lb. per cubic foot being 0.27 B.t.u. per sq.ft., hour, deg. F. and inch of thickness.

Even this brief resumé would be incomplete without reference to the factors important in mechanically coupling glass parts to each other or to other equipment. Dimensional accuracy of the glass part is important; equally so is reasonable care in assembly. Matching flanges, for example, should be aligned and should remain so throughout their required temperature or mechanical loading cycle. Surface areas to be clamped should be cleaned of residue from previous gaskets and should be free of fins, burrs, or wire edges. Clamping should be accomplished by uniform tightening of retaining ring or flange bolts in pairs in rotation, not over one-half turn at a time.

As demonstrating the adaptability of glass for mechanical parts, the centrifugal pump shown in the photograph is an excellent illustration. Capable of moving 50 g.p.m. against 45 ft. head, its casing includes a tangential discharge and is accurately shaped to produce satisfactory impeller clearances. The rotor is of the generally conventional open type, accurately ground and dynamically balanced to standards usual for pumps operating at 1,750 r.p.m. The resulting machine has demonstrated excellent hydraulic characteristics in experimental installations and tests.



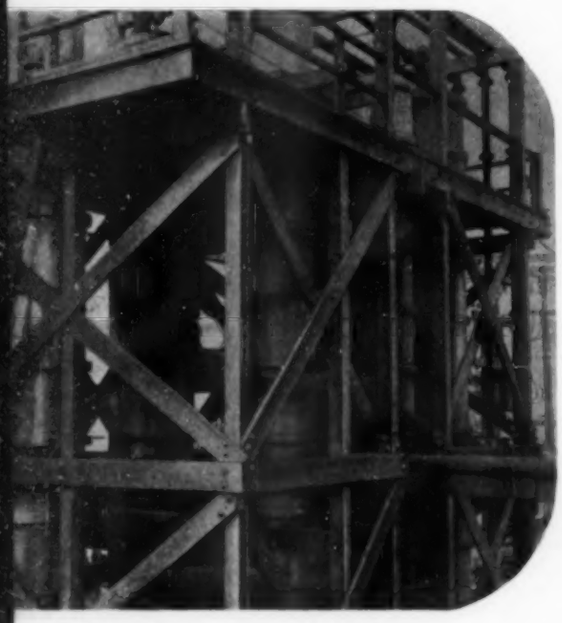
All-glass centrifugal pump for moving 50 g.p.m. against a 45-ft. head

CHEMICAL STONEWARE

By PERCY C. KINGSBURY
General Ceramics Co., New York, N. Y.

FROM the earliest times of which we have any record the production and processing of corrosive chemical materials have been carried out in ceramic ware and until a few decades ago this material was used almost exclusively for the purpose. Today special metals and alloys, synthetic and natural products are available to the chemical engineer from which to select the structural material best suited to his requirements, but there are still many operations in which the use of ceramic ware is indispensable and many more in which it has very definite advantages.

Of the ceramic construction materials, chemical stoneware is the most important one in chemical industry equipment and a steady increase in the production of this ware has followed the expansion in manufacturing chemistry and allied industries, notwithstanding the advent of new corrosion-resistant materials. Particularly is this true as many of the latter have not fully lived up to the advantages claimed for them.



Train of stoneware scrubbing towers, Great Western Electro-Chemical Co.

Stoneware has the widest field of usefulness of all the materials available for chemical equipment as its properties most nearly approach the glass and chemical porcelain of the laboratory. The applications of this ware in the chemical industry comprise almost every operation conducted at moderate temperature and pressure where corrosion is involved. Some of the more important of these applications are in the manufacture of chlorine, bromine and iodine, halogenated hydrocarbons, practically all mineral acids and their salts, many organic acids, hydrogen peroxide, photographic chemicals, pharmaceuticals, cosmetics, dyestuffs and intermediates. Outside the chemical manufacturing field, a large amount of stoneware equipment is used in electroplating and engraving, precious metal refining, metal cleaning and finishing, radium extraction, the chlorination of water supply, dyeing and bleaching, the development of photographic film and the preparation of foodstuffs, condiments and beverages. The standard equipment available in this ware and usually carried in stock includes pipe and fittings, plug cocks and valves, tanks, sinks and other containers, pumps, exhaust fans, kettles and stills, condensers and coolers, blow cases, towers and tower packing, gas generators and absorbers. About 80 per cent of the production is, however, to special design and made to order.

It will be realized that chemical stoneware is not a material of simple and unvaried composition. It comprises a range of ceramic products of widely differing physical properties but all possessing the unique resistance to chemical action characteristic of the silicates, being affected only by hydrofluoric acid and hot strong caustic alkalis.

The body consists essentially of finely ground particles of more or less refractory materials known as grog, suspended in a glassy matrix formed by clay mixed with a suitable flux brought to the fusion point at the kiln temperature. Partial solution and recrystallization at the interface between the grog and the glass result in the formation of complex eutectics that have an important bearing on the physical properties of the finished ware.

The physical characteristics with which the chemical engineer is chiefly concerned and their value for an average grade of chemicalware are as shown in the Data Sheet section of this issue, on page 656. Other characteristics not having absolute values but of interest to the ceramist in comparing one stoneware with another are pore volume and resistance to impact, abrasion and thermal shock.

By a suitable selection and proportioning of the raw materials and the degree of fineness to which they are ground it is possible to enhance one or more of the properties of a stoneware body to a very remarkable extent, sometimes at the expense of others as they are all more or less interdependent. The degree to which this is possible is limited by the fact that the mixture must also have certain working characteristics to enable it to be fabricated into the large and often complicated shapes demanded by the chemical industry. It must have a high degree of plasticity, uniform shrinkage in drying and firing, considerable strength in the unfired state and its vitrification range must conform to the temperature cycle maintained in the kilns. In order to meet these requirements it is necessary to blend, under careful laboratory control, clays selected from mines in various parts of the country. Formerly much of this clay was imported but this is no longer necessary.

About a dozen different bodies are required to meet the more commonly recurring conditions under which chemicalware equipment is used and these mixtures are carried in stock. Of these, some of the more recent are of special interest. By replacing a large proportion of the siliceous grog by silicon carbide a body is obtained that has 3½ to 4 times the thermal conductivity and mechanical strength of a regular grade of stoneware. This ware will not take the salt glaze usually employed for chemical purposes but special acidproof glazes have been developed for it, including a white glaze. A technique has also been worked out for grinding it by the conventional methods notwithstanding its extreme hardness. Such bodies were heretofore rather

porous but they are now no more so than the regular product. By the substitution of other materials in the grog special wares are prepared having extremely high resistance either to thermal shock, abrasion or mechanical stress. Regular stock mixtures are frequently modified as improvements are made and as deposits of raw materials give out or deteriorate and special bodies to meet exceptional conditions are constantly being developed.

It is therefore impossible to write a specification for a chemicalware body as one would for a metal or alloy. The manufacturer should be given specific information as to the nature of the product to be handled and the thermal and mechanical conditions to be met; the selection of the most suitable body and its preparation should then be left to his judgment. This is also true of the use of "de-airing" which is now frequently specified. A body to be de-aired is extruded in the form of a cylinder into a vacuum chamber where it is finely shredded so as to remove all occluded air, the material then being drawn out of the bottom of the chamber. All manufacturers are now provided with this equipment but the merits of de-airing are more in the improvement of the working qualities of the clay mixture than in the finished product. The chief advantage is a very great increase in the plasticity, which incidentally would make it possible for a manufacturer who was not too particular about the quality of his product, to reduce his manufacturing costs by the use of inferior raw materials that would otherwise not be sufficiently plastic to be workable. There is some small increase in the tensile strength and other desired characteristics of ware made from de-aired bodies but the use of this method of preparation is best left to the ceramist's judgment.

In writing specifications for chemicalware equipment, therefore, the practice of attempting to detail chemical composition, physical properties and manufacturing technique is inadvisable. Specifications should instead call for chemical stoneware to meet certain specified chemical, thermal and mechanical conditions.

The manufacturer of chemical stoneware equipment utilizes every method of forming known to the ceramic industry and finds little difficulty in making out of the plastic mass shapes to any design or dimensions that his manufacturing facilities can handle. The subsequent operations of drying and firing, however, introduce problems that have to be provided for in the design.

The shrinkage of a stoneware body during manufacture is 12-16 per cent or about 12 times that of cast iron, two-thirds of this shrinkage taking place during drying and the balance during the firing period. It is desirable, therefore, to keep wall thicknesses in a piece of equipment about the same throughout so as to insure uniform shrinkage and thus avoid internal strains in the finished ware. The wall must be heavy enough to support the weight of the piece and to sustain the stresses due to shrinkage while in the soft plastic state. If the wall is made too thick, however, it may not vitrify all the way through, leaving a soft, partially vitrified core in the center. Suitable wall thicknesses can best be determined by reference to the dimensions in manufacturers' catalogs of standard equipment of similar size and design.

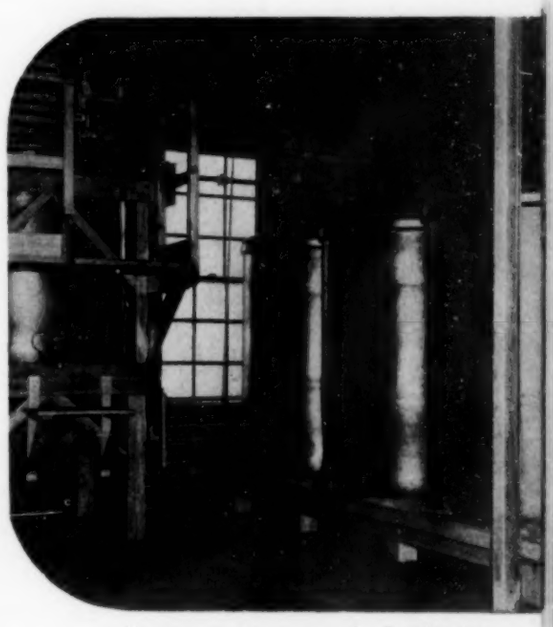
In pressure vessels and pipe lines, high-speed impellers of pumps and exhaust fans and similar shapes subject to mechanical stress, the usual practice is to allow a factor of safety of 10 and to test the equipment to 50 per cent above the maximum working conditions before shipment.

Stoneware vessels, pump housings, pipes, fittings, valves and other equipment that may be subjected to mechanical or thermal abuse are protected by inclosing them in a metal shroud, the intervening space being filled with a cement grout. Metal rods are similarly cemented into stoneware rolls, plungers, and other parts, to strengthen them or to serve as drive shafts. Metal reinforcements cannot be molded into the green ware on account of the shrinkage in drying and firing; also the firing temperature is considerably above the fusing point of most of the available metals.

In designing chemicalware equipment, consideration must be given to the fact that the material becomes extremely soft in the kiln as it approaches the vitrifying point. Dished covers should, for example, have a rise of about 25 per cent of the span, equivalent to a radius of curvature of five-eighths of the span. Unsupported vertical surfaces and long projecting outlets should be avoided where possible.

The practicable limit of size is determined by the dimensions of the kilns and is therefore not the same for all manufacturers. As an example, at one plant cylindrical shapes are made up to 5 ft. diameter by 6 ft. high and, due to the curvature of the kiln roof, for each 6-in. reduction in diameter the height can be increased about 1 ft., *i.e.*, a 4-ft. diameter cylinder can be made to the maximum height of 8 ft. Piping can be made in lengths up to 20 ft. or more, but such lengths cannot be handled in transportation and installation without great danger of fracture and consequently 5 ft. has been adopted as a convenient standard length.

Typical large rectangular shapes are tanks 11 ft. long by 2½ ft. wide by 2 ft. deep; 10 ft. long by 2½ ft. wide by 2½ ft. deep; 7 ft. long by 3½ ft. wide by 3½ ft. deep. The limitation here is the tensile stress due to shrinkage that the green clay



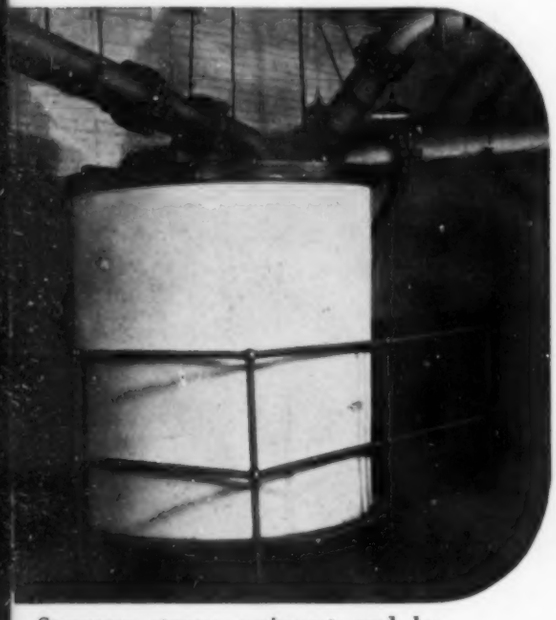
Stoneware storage and distributing equipment at Merck & Co. plant

can sustain. Taking the first of the above sizes as an example, a tank 11 ft. long, weighing in the green state about 2,500 lb., shrinks almost 2 ft. during manufacture and the resistance to this movement has to be overcome by tension in a soft plastic mass of the consistency of cheese. If the side walls are unduly high or heavy, the shrinkage of the tank bottom is likely to tear it apart. Consequently, on very long rectangular shapes there is a definite limit to the practicable width and depth as indi-

cated by the examples given above. They are intended merely to give an approximate idea of what can be fabricated in this ware. It is of course not possible to draw a hard and fast line between what can and cannot be made.

Tower sections up to 5 ft. inside diameter with flanged or bell and spigot joints present no manufacturing difficulties. They are usually made in lengths of 2½ or 3 ft. If perforated plates are used for supporting the packing material they should be spaced at intervals of 5 or 6 ft. Towers of larger diameters have been made but they introduce a number of manufacturing difficulties and are not encouraged.

Cutting, drilling, grinding and polishing of chemical stoneware can be carried out with extreme precision owing to the uniform texture of the ware and a number of ingenious ma-



Stoneware storage equipment used by Charles Gulden, Inc., New York

chines have been designed and built specifically for this work. Most chemical stoneware bodies are extremely hard, requiring the use of silicon carbide and diamond as cutting media. Stoneware can readily be cut to dimension in the field by hand but if a considerable amount of such work has to be done it is advisable to set up a small portable cutting wheel.

Joints in chemicalware equipment are usually flanged or of the bell and spigot type. Flanges may be cylindrical and are usually somewhat thicker than the wall of the pipe or outlet to which they are connected. Preferably, however, they are in the form of a cone. In either case the joint is tightened up by means of split metal collars conforming to the outside dimensions of the flange. Stoneware flanges with bolt holes or slots are seldom advisable. The face of the flange is usually ground and provided with annular grooves, the joint being made with a resilient gasket. Where a gasket cannot be used it is possible to polish the face so as to give a perfectly tight stoneware-to-stoneware joint. Small spigots and plugs are usually made with a tapered shank and fitted to outlets having a corresponding taper by lapping them in, similarly to the operation of grinding a valve into an automobile cylinder block. The solid angle of this taper is about 12 deg. but they are not exactly interchangeable and a final grinding, which is a very simple operation, is required to fit each tapered shank to its individual outlet.

Bell and spigot joints in chemical stoneware have deeper sockets with a narrower annular packing space than the standards adopted for sewer pipe. The joint is usually made by placing an asbestos cord loosely in the bottom of the socket which is then filled with a molten asphalt mastic poured from a ladle. The joint is frequently finished off with a topping of some inert material such as asbestos, ground silex or talc mixed with sodium silicate. Where an asphaltic packing cannot be used there are many other proprietary cements available and most chemical plant maintenance men have their own pet formulas. Various other methods are used for making joints in chemicalware equipment to meet special conditions, one common practice being to butt together the plain ends of cylindrical pipe and connect them with a rubber sleeve or to wrap the joint with asbestos cloth or other suitable material held securely in place by metal clips.

Owing to the nature of the manufacturing process and in particular the very high shrinkage during drying and firing, the finished dimensions of chemicalware equipment cannot be held to the precision possible in some other structural materials. Hence, due allowance for this must be made in the design. The variation is, however, less than with most clay products on account of the careful supervision necessary at all stages of the operation. A tolerance in linear dimensions of plus or minus 2 per cent is considered to be within the limits of reasonable accuracy. Equipment such as flanged pipe and fittings that is machined after firing should of course be exact to dimensions.

Ample time should be allowed for the manufacture of chemicalware equipment as it cannot be hurried without detriment to the quality of the product. The shaping in the green clay usually takes only a few days but two weeks is required for drying a piece of ware of average dimensions and large shapes with heavy walls or of complicated design may take a week or so longer. The firing cycle varies in different plants but in one plant with exceptionally large kilns it is about three weeks, of which two weeks is occupied in cooling down from the maximum temperature. This long cooling period has an important bearing on the quality of the ware as it has a similar effect to the annealing of glassware. It will therefore be realized that the shortest possible time required for the careful manufacture of any but small, simple shapes is about six weeks. If special molds have to be made or if there is any considerable amount of machining to be done after the ware is discharged from the kiln, the delivery will be correspondingly prolonged.

Chemical stoneware equipment is free from the failures due to corrosion experienced with other materials that are resistant to some chemical products but actively attacked by others. Failure of chemicalware equipment can usually be traced to the use of the wrong body or to faulty installation.

Chemical stoneware bodies differ in their physical properties as widely as do different grades of steel and must be selected with equal care with particular reference to the service expected of them.

Chemicalware equipment should be installed so as to allow for expansion and contraction, to minimize vibration and tensile stress, and to take full advantage of the extremely high compressive strength of the ware.

Installation details are beyond the scope of this article but can be obtained from manufacturers and, where important, are supplied with the equipment.

CARBON AND GRAPHITE

By F. J. VOSBURGH

Consolidated Carbon Div., National Carbon Co., New York, N. Y.

INERTNESS to all but highly oxidizing agents is the outstanding characteristic of structural carbon and graphite that in recent years has sharply increased the use of these materials in a wide variety of process industry applications. Brick, blocks, tile and special shapes of carbon and graphite are being used for complete towers, for linings of towers, vats, tanks and digesters, for atmospheric condensers and electrostatic precipitators. Tubes and pipes find their applications in the handling of corrosive fluids and in the construction of heat exchangers ranging from simple to complex.

For construction purposes carbon and graphite can be made as standard brick, or in shapes as small as 2 x 2 or 3 x 3 x 40 in., weighing 10 to 20 lb. each. At the other extreme they can be formed into blocks up to 15 x 30 x 180 in. or 24 x 30 x 180 in. weighing up to 7,600 lb. each.

All carbon can be machined, although not as easily as graphite which compares with hard wood in that quality. It should be kept in mind that carbon articles, like those of concrete, are much stronger in compression than in tension, that the strength to yield point and ultimate strength are practically identical and that there is no elongation in tension. Also, with the exception of specially made impervious carbon and graphite, all carbon is porous up to about 25 per cent and under pressure there will be slight seepage through the material. This factor may be relatively unimportant in many cases, since under some conditions the material handled will plug the pores and gradually stop the seepage. Carbon will oxidize in air at a temperature of 350 deg. C. (660 deg. F.), while graphite begins to oxidize at about 450 deg. C. (850 deg. F.). In general, the larger the carbon or graphite piece, the lower the strength characteristics, current carrying capacity, density, thermal conductivity and coefficient of expansion, and the higher the specific resistivity and permeability.

Carbon and graphite blocks, bricks, etc., can be cemented together with tar or pitch, or special carbonaceous cement, or with the usual cements generally offered by many manufacturers.

Carbon bricks are available in standard sizes of firebrick and can be made of graphite in the same sizes. The brick are generally used for the building and lining of equipment for use as pickling tanks for steel and for chemical reaction vats and towers. A number of manufacturers are in position to quote on complete installations requiring the carbon lining of equipment for the industry.

Raschig rings of carbon are an excellent packing material for chemical reaction, scrubbing and rectifying towers and for extraction systems. The rings are made in a range of sizes from ¼ x ⅛ x ¼ in. up to 3 x 2⅜ x 3 in. They are strong, chemically resistant, not affected by heat shock and are much lighter than most materials used for the same purposes. They are widely used in the oil and chemical industry.

Carbon and graphite tubes can be made having inside diameters of ¼ in. up to 10 in. and are normally carried in stock in a range of sizes from ½ in. I.D. to 6 in. I.D., with two larger sizes generally used for precipitator tubes also on hand. Regular quality tubes are slightly porous and liquids and gases under pressure will seep through them. This fact may not prevent their use for many purposes. The tubes may be machined so as to to be joined by couplings or flanges.

LARGE TILE SECTIONS—Previously large tile sections were made by boring holes through large electrodes, which resulted in a coarse grained, highly porous structure of low strength. One size of cast carbon tiles is now available, 38 in. O.D. x 33 in. I.D. x 36 in. long and other sizes will be made if there is a demand for them. Such sections can be machined to be fitted together with tongues and grooves. Openings may be made as required. This tile should find an application in chemical towers where chemical resistance is required.

IMPERVIOUS CARBON — Many carbon and graphite articles are made impervious by special treatment and tubes of carbon and graphite so treated are available in a range of sizes from ½ in. I.D. to 6 in. I.D. The impervious treatment changes the characteristics of the carbon and graphite to some extent. The treated materials are attacked by some chemicals that do not affect the untreated articles. The strength of the treated material is increased decidedly as is shown in the table of physical characteristics appearing in the Data Sheet section, page 658. The tubes are tested hydraulically to a pressure of 125 lb. per sq. in. and so can be used for the handling of gases and liquids without leakage. The heat transfer qualities of carbon and graphite are retained so that for heat exchange purposes a *K* value of 50 B.t.u. per square foot, deg. F., hour and foot of thickness for graphite and one-tenth of that for carbon are standard values. In the case of graphite the value is higher than that of steel.

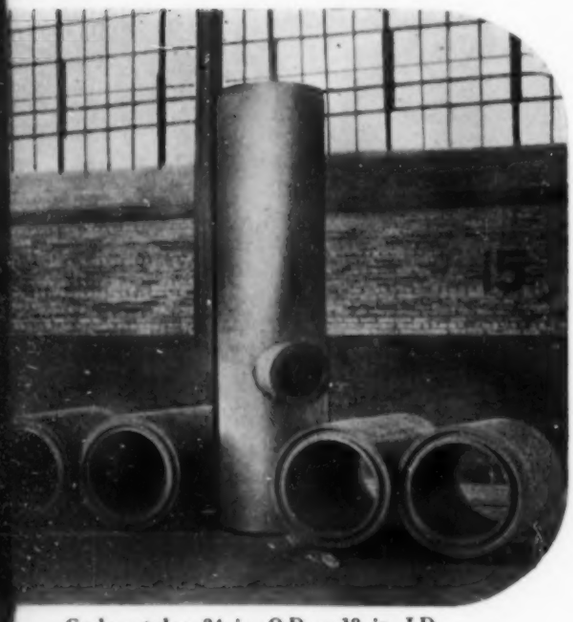
Carbon brick lined pickling tank during construction, before cementing joints

The impervious materials can be machined before or after impregnation and may be threaded for coupling or flange joining for use as pipe for handling corrosive liquids or gases. The materials are entirely unattacked by hydrochloric acid at any concentration and any temperature. Such impervious materials are highly resistant to heat shock but have a tem-

perature limitation of 175-200 deg. C. Because of their high heat transfer rate they can be used in much higher temperatures if one side is kept below the critical temperature by cooling agents. The materials are fragile as compared to metals but in general more rugged than glass.

Fittings such as elbows, return bends, tees, flanges, etc., can be machined from stock materials and treated to be made impervious. Stream-lined elbows and U-bends are available in several sizes.

POROUS CARBON—This material is porous to a far greater degree than the normal porosity of carbon and the porosity is of a different quality and more definitely controlled than is the case in the regular grades of carbon or graphite. Porous carbon has all of the usual qualities of carbon—chemical and thermal-shock resistance, electrical conductivity, low coefficient



Carbon tubes 24 in. O.D. x 18 in. I.D. for an acidproof tower 24 ft. high

of thermal expansion—but the material is definitely weaker than the usual grades of carbon. (See table in Data Sheet section, page 658.) The porosity can be so controlled that the water permeability can be varied from less than 1 gal. per sq. ft. per minute through a plate 1 in. thick under a pressure of 5 lb. per sq. in., to 200 gal. under the same conditions. The air permeability can be varied from less than 1 cu. ft. per sq. ft. per minute through a plate 1 in. thick, with a pressure differential of 2 in. of water, to 43 cu. ft. per minute under the same conditions.

The size of particle removed by the porous material will vary in diameter from 0.0005 in. to 0.006 in. dependent on the grade of carbon. Special grades are available which will remove even finer particles.

Porous carbon and graphite should find a wide field of application in the filtration of gases, oils and various liquids generally considered hard to handle in the chemical, plating, pickling and paper industries. An equally large application should be found in the diffusion of gases into liquids, for the agitation of liquids and the separation of gases from gases and gases from liquids.

Another interesting characteristic is the high capillarity of some grades of porous carbon and the fact that if used for that purpose the solids which are normally deposited in the pores of other porous materials are deposited on the outside of porous carbon.

SILVER FOR PLANT USE

(*Continued from page 601*)

and 20 ft. in length as well as drawn tubing up to 20 in. in diameter have been produced.

Electroplated silver equipment is plated with from 0.004 in. to 0.02 in. thickness of silver, depending on the service requirements. This method is difficult to apply to large scale equipment, however. Some of the largest equipment of this type is a group of shallow silver-plated tanks 25 ft. long and 4 ft. wide. Heating coils, small tanks, boiling vessels, photographic rolls and beverage dispensing equipment are typical applications of silver plating.

Silver linings may be provided for vessels by use of inserts of sheet silver which may or may not be attached to the shell of the vessel. The preformed basis metal can be plated, or, less conventionally, a shell of sheet silver may be built up electrolytically with an external deposit of copper or other metal to provide strength and rigidity. Brass tubing may be lined with a silver tube or a silver tube may be drawn over a brass tube. Heat transfer measurements on a silver-lined brass tube indicated no loss in efficiency at the interface. Other base metals may be used as the support for the silver, whether externally or internally applied.

Silver-clad nickel and silver-clad steel are now available in plate and sheet up to 25 in. width; silver-clad copper is available in greater widths and is also obtainable as tubing. The silver is commonly 10 per cent or 16 per cent of the clad steel plate in thickness. Other ratios, of course, are possible.

Silver is applied in chemical equipment in many forms, of which the following are typical: stills, condensers, autoclaves, tanks, trays, piping, heating coils, reaction vessels, evaporating pans, crucibles, molds, ladles, siphons, rolls, valves, cocks, containers, filter screens, and distilling column chains.

A large use of silver equipment is in the manufacture and handling of organic acids such as acetic, lactic, formic and carbolic, particularly the first-named. Condensers, stills, vats, taps, etc., of silver are used in the manufacture of acetic acid and its derivatives and find use in the manufacture of acetate rayon and vinegar for pickling purposes. Silver equipment finds important uses in the manufacture of organic preparations, as in the pharmaceutical and dyestuffs industry. It is used in the preparation of the purest grades of fused sodium and potassium hydroxide. Silver apparatus is also used in the manufacture of ink, in the tanning industry, and in the handling of essential oils and perfume essences.

The author has been interested in two types of silver alloys which appear promising in regard to possible application in the chemical industry, namely, the low silver-tin alloys and the high silver-low silicon alloys.

The alloy of tin with 3-3.5 per cent silver offers a material characterized by the corrosion resistance of block tin but materially stronger and harder; tests show that this alloy in the form of tubing has nearly double the bursting strength of unalloyed tin tubing, is more resistant to plastic deformation on sustained loading, and is chemically suitable for distilled water piping and similar applications. Experimental work with silver alloys containing less than 2 per cent silicon, the remainder being silver, indicates that this type of alloy may be as corrosion-resistant as fine silver while possessing higher yield strength and hardness. The silver-silicon alloys in this range of composition show appreciable response to hardening by heat-treatment.

PLASTIC MATERIALS

By C. R. RUNK.
Engineer, Haveg Corp., Newark, Del.

SYNTHETIC RESINS ARE RESISTANT to the attack of most chemicals. This fact has been known for many years, but manufacturing limitations have prevented widespread industrial use of resinous equipment. However, the difficulties have now been overcome and the resins are gradually becoming popular as materials for construction of equipment for use in process industries.

The laminated or molded phenol-formaldehyde products, usually referred to as Bakelite, has become widely used where good mechanical properties are required and where the chemical concentrations are low. This product is available under various trade names. It has been used extensively in the textile industry for the construction of pipe lines, valves, rayon spinning buckets, rolls, bearings, gears, bobbins, spools and many special mechanical parts. The pulp and paper and other industries also have developed numerous uses for this type of product. The limited resistance of the filler has prevented heavy chemical producers using it except in a few cases such as pipe lines for neutral or slightly acid solutions; drying trays, agitator parts and other items which could be fabricated easily from standard production.

The material is available usually in stock as sheets, rods, tubes, and molded pipe fittings. It is light in weight (Sp. G. 1.35), machines readily, and is easy to assemble. Pipe is furnished in lengths up to seven feet and may be cut and threaded with standard pipe threads. Lines are assembled with the molded threaded fittings or special fittings such as the Dresser type of coupling. Care should be taken not to pull up the threads too tightly as they do not have the strength of metal threads. Such lines are normally recommended for operating pressures up to fifty pounds. It is necessary to use expansion joints in the line to allow for a slight elongation which occurs after the lines have been placed in service.

To use the resins for plant size equipment and meet the severe corrosion encountered in the heavy chemical industries, it became necessary to find a filler which would be resistant to chemical attack. This was accomplished by the use of special grades of acid digested asbestos. The next step was to develop a manufacturing technic which would eliminate high charges for molds. This too was soon accomplished and resulted in the molded phenolic asbestos plastic, Haveg.

The essential properties of this material which make it especially valuable in the chemical industry are:

(1) Resistant to chemical corrosion.
(2) Strength and durability for large scale equipment.
(3) Reasonable cost because of low priced manufacturing equipment.
(4) Quick delivery from short manufacturing cycle.
(5) Elimination of electrolytic corrosion.
(6) Resistance to thermal shock and boiling temperatures.
(7) Elimination of metallic contamination.
(8) Ease of assembly due to light weight (Sp. G. 1.6).
(9) Machinability—pipe and fittings may be cut to length on the job.

With such an array of desirable characteristics, Haveg has found many applications. It is well, however, to note its limitations. These are principally:

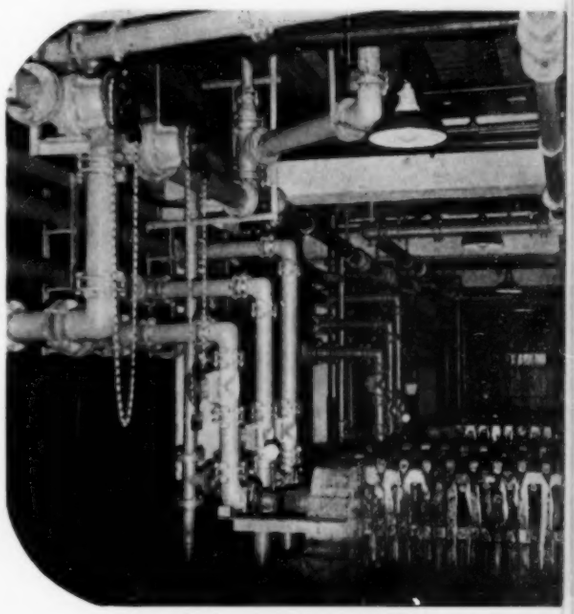
(1) No resistance to certain strong oxidizing agents such as nitric and chronic acids.
(2) No resistance to such solvents as normally attack the phenolic type of resins.
(3) Limited uses with strong caustic conditions.

Briefly, Haveg is supplied in one piece molded construction in single units ranging in size from a quart dipper to a 5,000 gallon tank. The finished vessels have a compact, impervious, homogeneous structure with smooth jointless surfaces. Larger equipment is provided by assembling flanged units to provide practically any size or shape of tank required.

In addition to the applications found for Haveg tanks, pipe and valves, its extensive adoption for plant equipment is indicated by the following uses: absorbing and scrubbing towers, agitators and stirrers, crystallizing dishes, drying trays, evaporating and concentrating equipment, filtration equipment, fume duct and fan housings, regulator valves and thermometer wells, rolls, reels and guides, textile agers, and textile dyeing equipment.

The pipe and fittings for handling corrosive liquids are supplied in standard sizes from ½ in. to 12 in. and in lengths up to 10 ft. The pipe is simple and rugged, easily installed, can be used hot without damage from thermal shock, and is easily machined to length in the field. It can be used with moderate pressures, and does not usually need to be insulated against heat loss.

The pipe is normally connected by means of slit cast iron flanges set in tapered slots machined near the ends. Straight threaded sleeve connections, bell and spigot, and several other connecting methods are also available where special conditions require them.



Several thousand feet of Haveg piping conveying chemicals in this plant

It is recommended that Haveg-bodied Hills-McCanna Saunders diaphragm valves be used.

Constant efforts are being made to develop new resins and overcome limitations of the present ones. Already a resin resistant to strong caustic has been developed and is being used in trial installations. This resin has been designated as Haveg 50. The tests indicate extensive application for equipment where resistance to both acid and alkali is required in the same vessel.

RUBBER COMPOUNDS

By H. H. HARKINS and O. S. TRUE,
U. S. Rubber Products, Inc., New York

WITHIN THE PAST FIFTEEN YEARS, rubber linings for industrial use have been developed to a point where they are being advantageously applied to many types of process, storage and distribution equipment. Of primary importance in this growth have been the improvement of adhesives for bonding rubber to metal and the development of rubber compounds capable of meeting more severe requirements, both chemical and mechanical.

Crude or raw rubber is not widely used as such in the chemical industries because of the fact that it is thermoplastic. Ordinarily when speaking of rubber we mean vulcanized rubber. There are instances, however, where unvulcanized rubber is preferred to vulcanized rubber, a notable example being the use of unvulcanized gum to line wooden tanks for the storage of hydrochloric acid. Since vulcanized rubber is the most important we will confine our attention to that.

Intricate equipment such as this mixer can be protected with rubber

For practical purposes, three types of rubber should be distinguished: soft rubber, semi-hard rubber, hard rubber or ebonite. These products, alone or in combination with each other, constitute the rubber constructions used in industry for the protection of metal equipment.

Soft rubber comprises those rubber-sulphur combinations with a coefficient of vulcanization of 0.5 to 8 wherein 0.5 to 8 parts by weight of sulphur are chemically combined with 100 parts by weight of the rubber hydrocarbon. Soft rubber is characterized primarily by its high elongation, strength and resistance to abrasion. Properly compounded soft rubber also possesses good resistance to water and various corrosive chemicals at moderate temperatures.

Semi-hard rubber is characterized by a vulcanization coefficient of 8–30. Hard rubber includes those products having a coefficient of 30–47. Ebonite is rubber fully saturated with sulphur and has a coefficient of vulcanization of 45–47.

Semi-hard rubber is useful as a lining material primarily because it has greater flexibility and stretch than hard rubber and better chemical resistance than soft rubber. Chemically and physically it is intermediate in properties between soft and hard rubber.

Hard rubber is more resistant to chemicals and heat than is soft rubber or semi-hard rubber. Large steel surfaces subject to temperature variation, however, cannot be satisfactorily protected with ebonite alone, since the coefficient of expansion of hard rubber is much greater than that of steel. Use is therefore made of combinations of soft and hard rubber, soft and semi-hard rubber, as well as semi-hard and hard rubber combinations in order to adapt rubber to industrial equipment and to take advantage of the excellent chemical resistance of hard rubber.

The physical properties of soft and hard rubbers are listed in the Data Sheet section on page 661.

Adaptability of Rubber

The development of rubber-to-metal bonding agents is responsible for the present widespread use of rubber as a lining material. Steel equipment, rubber-lined, is the most widely used of rubberized chemical equipment. In recent years, however, adhesives have been developed which make it possible to bond rubber to aluminum, bronze and brass, as well as to most structural metals and alloys. The rubber-to-metal bond will hold rubber in place over the temperature range where rubber is useful; that is, up to 220 deg. F.

Equipment may be rubber lined in the rubber manufacturer's plant or in the field. Ordinarily it is customary to apply the bonding agent and the sheet rubber to the equipment, place it in a closed vessel (vulcanizer) and vulcanize the lining in place by the application of steam under pressure. The application of rubber linings is by no means confined to this procedure, since satisfactory linings of either soft or hard rubber can be applied in the field and cured at temperatures of 150–212 deg. F. in exhaust steam. Many installations have been made in the field in this manner. An alternative method for doing this consists of compounding rubber with certain amines, shipping the sheet rubber, applying it in the field in the usual way and then treating the rubber (in place on the equipment) with carbon bisulfide. The amine in the rubber reacts with carbon bisulfide to form a powerful low temperature accelerator. After this reaction has taken place, the rubber may be vulcanized by the application of very little heat, or, in the case of soft rubber, at atmospheric temperatures. For cases where the use of carbon bisulfide is objectionable, rubber compounds are available which can be vulcanized to either soft or hard rubber at temperatures of 180–212 deg. F. without the use of carbon bisulfide. Also, in the case of soft rubber it is possible to apply linings not requiring carbon bisulfide which will give a high grade stock when vulcanized for 4 to 5 days at temperatures of 100–110 deg. F. In spite of the low curing temperature, excellent adhesion to steel is secured in this manner.

It is obvious that the above principles are applicable to the repair of rubber linings in the field. The fact that rubber-lined equipment can be repaired satisfactorily in the field is of great practical importance. If it were not possible to repair rubber in the field, it would be necessary to ship the equipment to a manufacturer's plant in order to repair a slight damage. Obviously this would not be economical.

It is fortunate that when rubber-lined equipment is damaged mechanically, corrosion is largely confined to the point of injury. Repair can be made by taking off the damaged rubber, cleaning the metal, applying adhesive and unvulcanized sheet rubber in the same way as done in rubber lining the equipment originally.

The adaptability of rubber to factory or field application, together with the fact that rubber is very resistant chemically, makes possible a broad range of application in the chemical industries. Practically all inorganic acids and salt solutions can be handled in rubber-lined equipment. Strong oxidizing solutions, however, such as nitric and chromic acid, attack rubber readily. Other oxidizing solutions, such as sodium hypochlorite, chlorine water, dilute nitric and chromic acid, attack rubber slowly, and so rubber-line equipment has an economical life.

One of the outstanding properties of soft rubber is its resistance to abrasion. Chemical processes which involve handling of abrasive slurries can use rubber to great advantage regardless of whether the material handled is corrosive or not.

Limitations of Rubber

While rubber is inert chemically to many corrosive solutions, it is readily swelled and weakened by contact with aromatic and aliphatic solvents. Chlorinated hydrocarbons also swell and disintegrate rubber. For this reason care must be exercised in applying rubber to equipment which is to come in contact with these materials. Hard rubber is quite resistant to petroleum solvents at ordinary temperatures and can be used satisfactorily in certain cases where petroleum oils are present. For example, hard rubber compounds can be applied as roll covers for use in molten paraffin at temperatures of 150–180 deg. F.

Rubber-lined equipment is also susceptible to mechanical damage. The lining may be punctured by contact with sharp-pointed objects, or, in the case of hard rubber, cracked by impact of falling objects. Where mechanical abuse is severe, it is customary to protect rubber by placing over it a sheathing of brick held together by a suitable acid-proof cement. Combinations of steel, rubber and brick are widely used in pickling baths for steel.

Rubber has definite limitations with respect to temperature. It does have satisfactory resistance to most aqueous solutions up to their boiling point. Hence, in spite of the fact that there is a comparatively narrow temperature range in which rubber can be used, its use covers a broad range of corrosion problems since these problems are largely associated with aqueous solutions.

Design and Fabrication

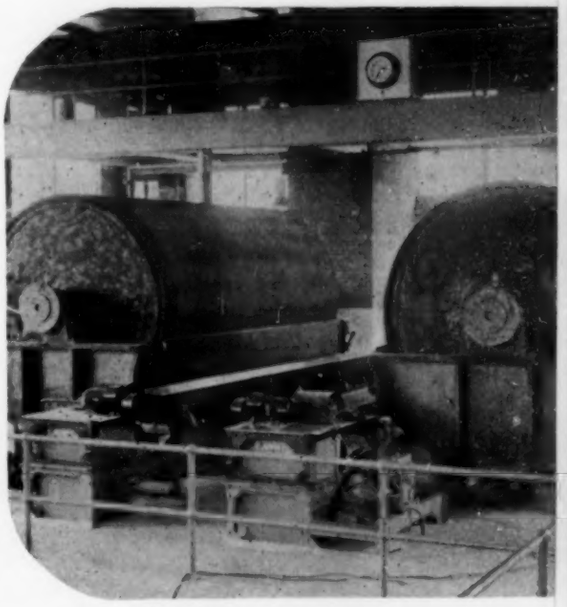
Since rubber linings and protective coverings are adhered to a rigid supporting member, usually of steel, their range of application insofar as design is concerned is limited only by the structural limitations of steel itself. It is, of course, necessary in the case of closed vessels that suitable manholes or other openings be provided for entrance of men and materials, and in the case of complex units it is necessary that surfaces to be rubber covered be sufficiently accessible to permit the proper application of materials. In many cases standard equipment items are suitable for rubber lining or covering with little or no alteration in design, such as pipe and fittings, valves, fans, tank cars, agitators, continuous filters, vacuum crystallizers, screw conveyors, and classifiers. Equipment which can be transported by rail is best handled at the rubber factory. Non-transportable equipment can be rubber lined in the field, there being no practical limit to the sizes involved.

The chemical industries offer many examples of the satisfactory use of rubber-lined equipment, both with regard to type of equipment and chemical and physical conditions.

The manufacture, distribution and storage of hydrochloric acid usually involve rubber linings all along the way. Rubber-lined reaction chambers, absorption, settling and filter tanks, exhaust fans, pipe and fittings, tank cars, are used in the manufacture and distribution of phosphoric acid of food product grade. Rubber-lined collector flues, absorption towers, and filter tanks, are used in the production of hydrofluosilicic acid. Rubber-lined mixing tanks are used in the manufacture of commercial bleach. Rubber-lined absorption towers are used for gaseous reactions, such as formation of chlorides, both organic and inorganic. Rubber-lined filter tanks handle the effluent in connection with pigment precipitation. In the process industries rayon manufacturers use rubber linings for various types of bleach and wash tanks and in the handling and treatment of spent spinning solutions. The recirculation of electrolyte in the electrolytic refining of various metals frequently employs rubber lined pipe, fittings and valves. A distinct advantage is the elimination of stray current losses. Pickling of steel is carried out in rubber-lined tanks, while paper mills employ rubber linings in bleaching, filtering and stock distribution; and municipal sanitation, in chlorine and ferric chloride processes.

SYNTHETIC RUBBERS

THE SYNTHETIC rubber-like materials such as Koroseal, neoprene, Plioform, Resistoflex and Thiokol, are becoming increasingly important where rubber-like properties are required along with resistance to solvents,



Rubber-lined continuous filters in use in sewage disposal plant

hydrocarbons and other chemicals.

Their use for tank linings and pipe linings has not been developed as far as in the case of rubber, though such linings are entirely possible and rapid progress is being made in perfecting them. At present they find their widest application in the form of molded articles, hose, hose linings and fabric coatings.

Information on the chemical and physical properties of these materials will be found in the Data Sheet section on page 661.

WOOD FOR CHEMICAL NEEDS

By JAMES K. STEWART
Consulting Chemist, Crescent Mills, Calif.

EVEN IN THIS MODERN INDUSTRIAL ERA wood still plays a major part and serves the chemical engineer especially as one of his most important materials of construction. This article endeavors to point out some of the characteristics of wood when used to build tanks, vats, other containers and pipe for chemical process industries. Conclusions expressed here are based on new data resulting from recent tests upon eight varieties of wood; viz., fir, oak, Oregon pine, yellow pine, spruce, redwood, maple and cypress.

Principal sources of concern in the design of wood equipment are: absorption of solution by the wood, contamination of the product, shrinkage or swelling of the wood and destructive effects of chemical action.

The first of these, absorption, is important for two reasons. First of all,

12,000 gal. wooden tank for storing 35-40 per cent ferric chloride

in the case of an expensive solution, much of the product may be lost by absorption in the equipment. Secondly, and of more importance, a wood having high absorption of an active chemical will be more vulnerable to the action of that solution than one with a low absorption. Consequently, a low absorptive wood should outlast a high absorptive wood under parallel conditions. According to the results of tests conducted on blocks of tank stocks of various woods, the order of suitability for cold solutions would be: redwood, spruce, fir (Oregon pine equal), cypress, yellow pine, oak, and maple. For hot solution the order is: oak, maple, Oregon pine, redwood, yellow pine (spruce equal), and cypress. In these determinations the amount by volume alone of solution absorbed was considered.

Contamination of Product

Wood may contaminate the product in several ways. The most important of them is in the impartation of a color to the solution. In ordinary operations this is not of very serious consequence; however, if color is detrimental it may be preferable to use a wood which yields the least coloring matter or which ceases to do so after a short time, such as fir, maple or cypress. In most cases the volume of solution will be so great that any color taken up will be scarcely noticeable. Hot solutions do, of course, extract more coloring matter than cold ones.

Flavors and tastes derived from the wood by liquids are not generally objectionable in most process industry uses. It was found that redwood, maple and cypress impart the least taste to solutions. Gums and resinous matter freed from the wood by the solution, is often a source of trouble but may usually be eliminated by preliminary extraction.

Change in Volume

Temporary change in volume is more important than permanent change in volume as the permanent change is a constant factor that may be considered throughout the life of the vessel, while temporary changes may vary from solution to solution. In this case, the order of suitability of the wood will be as follows: For cold solutions, redwood, yellow pine, spruce, Oregon pine, cypress, fir, maple, oak; for hot solutions, redwood, yellow pine, spruce, Oregon pine, fir, cypress, maple, oak.

Effect of Chemical Action

In general it may be said that a solution which destroys the fiber of a wooden vessel dissolves either the cellulose or the lignin or both. Some solutions attack the cellulose only, others attack the lignin only, and some attack both cellulose and lignin. Hardwoods contain more lignin, softwoods contain more cellulose; hence the nature of the solutions determines the type of wood to be used in a particular installation. Another generality is that wood is usually more resistant to weak solutions than to concentrated solutions, all other things being equal.

Sulphuric and hydrochloric acids appear to affect all woods detrimentally, although weaker solutions of the same acids do not injure them to any serious extent. Acetic acid at any concentration seems to be without any action, that is destructive action, on any of the woods, and the wood selected for use with this acid should be that which yields the least coloring matter to the solution. Potassium and sodium cyanide solutions under normal conditions are practically without action on all woods.

In general all woods appear to withstand the action of acids and acid solutions better than they do strongly alkaline and caustic solutions. The latter attack and disintegrate the fiber, but weak alkaline solutions do not affect the wood to any great extent. Lime, magnesia and iron solutions are most detrimental to wood and appear to have an actual corrosive effect.

Strong oxidizing agents should not be brought into contact with wood as they rapidly destroy it by structural decomposition. The cellulose is easily converted to oxy-cellulose, a brittle substance with practically no coherent properties. Nitric acid, chromic acid, potassium permanganate, and free chlorine are particularly active in this respect.

At ordinary temperatures a solution may have no appreciable action on wood for an indefinite period, but an increase in temperature may cause immediate and rapid destruction of the material. Further, this effect appears to be proportional to the degree of temperature rise. More detailed information along this line may be obtained by reference to tables on Page 662 of the Data Sheet section.

RESEARCH

As An Educational Agency

Too often the technical man fails to see the important contribution that he can make to his company's broad program of public relations. Yet there is no better agency than the research and development department to disseminate information that will create a favorable attitude toward a company's policies and products.

By A. J. WADHAMS
Vice President, The International Nickel Co., Inc.,
New York, N. Y.

A QUARTER OF A CENTURY ago industry was restricted to a few simple metals and alloys, and was hampered by cut-and-try methods, in the design and manufacture of equipment. It was only as metallurgy was broadened from a subject in the curricula of the technical schools into an accepted function of industrial practice, that the emphasis could be changed from making the best of available materials to creating materials to meet specific needs. More importantly still, it was only as metallurgical advances became the subjects for interchange of information and experimentation not merely between sections but even between nations, that the industrial world was able to move into its present stage of performance.

In this modern development nickel has become so inextricably woven into the fabric of world industry that much of the performance which we now expect in transportation, communications and manufactured products depends on uses of that metal and its alloys.

How this status of nickel has been achieved in such a comparatively short time is one of the great examples of successful public relations. It is based on a policy of first learning, then doing, and finally talking. A thorough going research was instituted into the properties of nickel alone and as a constituent of various alloys. What was learned was carefully tested in the laboratory, then demonstrated under conditions of commercial production, and finally made the text of intensive educational programs in the appropriate industries. Coincidentally, other industries became interested in seeing what they could do along similar lines. Metallurgical research was stimulated in various fields. The "Age of Alloys" began to take shape with nickel in the position of common denominator among many of the new metallic combinations.

Behind this development there has been leadership inspired by faith in the product as well as faith in research and development. The research laboratory at Bayonne, N. J., has twice been expanded and modernized to keep pace with the demand for ever more exact knowledge of nickel and nickel alloys, and of their behavior under ever more exacting conditions of use. Since the incorporation into the International Nickel Co. of The Mond Nickel Co., Ltd., its laboratory in Birmingham, England, has greatly strengthened research facilities. This laboratory, which also was recently enlarged, is said to be the largest and most modern institution of its kind to be maintained by any industrial corporation overseas. The research facilities have been further strengthened by the construction of a modern laboratory at Copper Cliff, Ont.

Supplementing the research staffs, both here and abroad, is a corps of metallurgists in New York and London whose function it is to offer technical service to industry in the introduction and adaptation of nickel and nickel alloys to their special needs. The corps includes specialists with practical experience in one or another of the fields of rolling mills, foundries, electroplating establishments, railroad shops, automobile plants and specialized industrial activities. Thus is offered a type of cooperation which wins the confidence of the man on the job in the plants where nickel products are used. At the same time these metallurgists are active in the various technical associations, holding offices or committee chairmanships, frequently submitting papers to the national and chapter meetings of the societies.

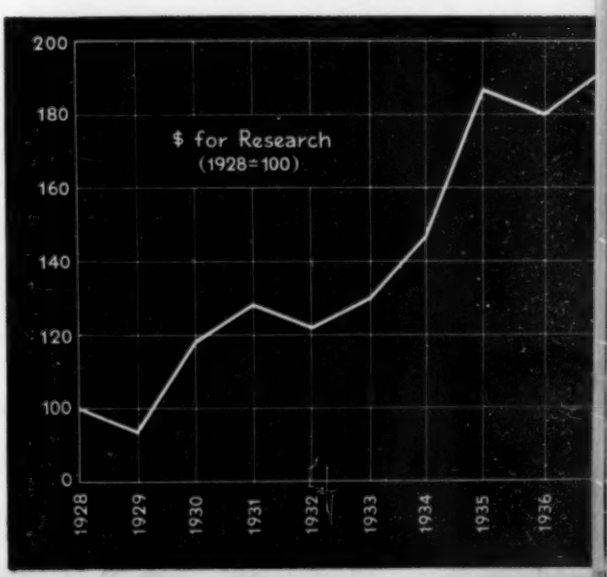
The success of the technical service has been such that New York headquarters of the Development and Research Division can no longer handle the requests for aid. Branch offices have therefore been established in Detroit, Chicago, Pittsburgh, Los Angeles and Hartford.

Further expanding this missionary work to world industry, Nickel Information Bureaus have been established in Paris, Brussels, Milan, Frankfort and Tokyo. These are centers for collecting information on important metallurgical developments in their territories, and for translating and circulating to their constituencies pertinent reports.

Large sums of money have been invested in these research laboratories and equipment in Canada, the United States and Great Britain, and employment has been given to several hundred men.

Laboratory at Copper Cliff, Ont., recently added to company's research facilities

Trend in annual research expenditures by International Nickel



(*Continued from page 600*)

of the furnace. After annealing in fully reducing atmospheres, the surface will be silvery white with no traces of oxide following this quench. The chromium oxide on Inconel is not reduced in the alcohol quench.

BOX ANNEALING—The boxes should be luted carefully with clay or sealed with sand or other suitable refractory material. Willow charcoal may be packed with the charge. The boxes should be provided with a hole to admit a small pipe for gassing during cooling to prevent the inflow of air. City gas, natural gas, acetylene, propane, hydrogen, or mixed gases may be used. The gas is admitted immediately on drawing the box from the furnace, or on shutting down the burners. The flow should be regulated to burn gently at all possible leaks.

The total time in the furnace will depend largely on the size and weight of the box and charge, and on the furnace heating capacity. The following data give the required time at temperature, to which must be added the time for heating up:

	Deg. F.	Deg. C.	Hours
Inconel.....	1500	814	2 to 6
Monel.....	1400	760	2 to 6
"A" Nickel...	1300	704	2 to 6

Cold Working

The cold working technique used in forming Monel, nickel and Inconel is essentially the same as used on mild steel for bending, forming, drawing, pressing, swaging, cold forging and power hammering. Their high strengths limit manual operations such as spinning, bumping and hand hammering to comparatively easy shapes.

Standard wrought Monel, nickel and Inconel are work hardening materials. The chart on p. 600 shows rates of work hardening of these and other commonly used metals. This chart indicates that the high nickel alloys work harden more rapidly than the softer materials, and may require more frequent anneals during a severe forming operation. However, the high ductility of Monel, nickel and Inconel allows these metals to be worked severely without fracture, even though greater power is required than with the softer materials.

TUBE BENDING—Annealed tubing should be ordered for cold coiling or bending, and tube ends should be annealed for cold Van Stoning. There is no essential difference in bending and coiling between these materials and steel. Proper bends cannot be made without using dies to confine the wall. Practical experience has demonstrated that with proper bending equipment using a mandrel, annealed Monel and Nickel tubing can be cold bent to a mean radius of two diameters or greater, provided the wall thickness of the tube is not less than 1/20th of the outside diameter, e.g. 1 in. O.D.—.050 in. wall. In bending without a mandrel, the mean radius must be increased to at least three times the O.D., and the wall thickness should be not less than 1/15th the O.D., e.g. 1 in.—.065 in. wall. This includes all iron pipe sizes up to and including 2½ in.

With metal fillers, such as the Woods metal type, "U" bends have been made with ¾ in. O.D. .025 in. wall on 2¾ in. centers and 1 5/16 in. O.D. .072 in. wall on 3½ in. centers. These were made in tube bending equipment.

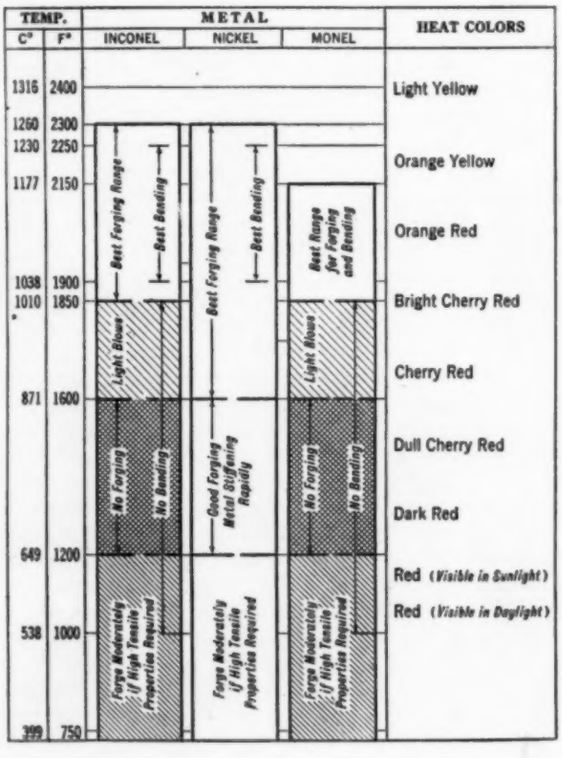
Hot Bend Only Heavy Tubing

Hot bending is confined to heavy wall tubing because the light walls do not retain heat sufficiently long to give good results. On I.P.S. sizes up to 2½ in., hot bends may be made with mean radii equal to two diameters. It is necessary to increase the radius for larger size tubing. For example, 6 in. nickel I.P.S. tubing has been bent on a mean radius equal to four diameters.

The same heating precautions should be observed in hot bending tubing as were described for forgings. Bending should be done near the top of the forging range.

PUNCHING AND PERFORATING—Because of the toughness of high nickel materials, the minimum diameter of the holes that can be punched on a commercial basis must exceed the thickness of the sheet up to thicknesses of approximately $\frac{5}{32}$ in. to $\frac{1}{8}$ in., where the minimum diameter of the hole may be equal to the thickness of the sheet. General rules in selecting the minimum size of hole that can be punched practically in a given thickness of soft to skin hard Monel sheet, are given in the tabulation below:

Thickness of Sheet	Minimum Diameter of Hole
.018 in. to .037 in. incl.....	Thickness × 1.50
.042 in. to .062 in. incl.....	Thickness × 1.30
.078 in. to .125 in. incl.....	Thickness × 1.20
$\frac{5}{32}$ in. and up.....	Thickness × 1.20



Approximate temperature ranges and heat colors for use in forging, bending and otherwise hot-working Monel, nickel and Inconel in the manufacture of chemical engineering equipment

Machinery, Materials and Products

Novel Skid System

LOW INITIAL COST and easy, efficient operation are important claims for the JackMaster material handling system recently announced by the Lewis-Shepard Sales Corp., 245 Walnut St., Watertown, Mass. The new device consists of a semi-live skid and a two-wheel lifting unit. That is, the skid employs a pair of metal or rubber-tired roller bearing wheels at one end, with standard skid feet at the other end. The lifting unit comprises a handle supported on two wheels which, when the handle is vertical, may be hooked under the dead end of the skid and the handle pulled forward so as to lift the load. It is stated that the load may be lifted either left or right through an arc of 170 deg. The lifting unit stands in an upright position when not in use. It is said to be impossible for the lifting unit to break away from the skid while the load is being transported. Three standard sizes are available in capacities from 2,500 to 3,500 lb.

Spiral Heat Exchanger

SEVERAL VARIETIES of spiral heat exchanger in which exceptionally large amounts of heat exchange surface are packed into relatively small volume have recently been introduced into the United States by the American Heat Recovery Corp., 1270 Sixth Ave., New York, N. Y. Exchangers of this type were developed in Sweden and have been used for the past several years in most of the European countries, particularly in pulp and paper plants and sugar mills. Other applications have been found in oil refineries, breweries and yeast works, smelters and chemical plants and in a number of miscellaneous uses.

In contrast to the tubular design common to most types of surface heat exchanger, the spiral type is built up of two plate spirals placed one within the other so as to form two spiral passages, one for the hot and the other for the cold fluid. The width of these passages is obviously easily adjusted in the design to yield the most suitable mass velocity of flow. By altering the method of connection, the construction lends itself to either con- or counter-flow, or to cross-flow. Three classes of condenser have been developed. Type I (illustrated) is used for two liquids—generally in counter-flow. Type II, a cross-flow condenser, is used chiefly for recovery of heat from large quantities of gases or vapors. Type III, for exchange of heat between a smaller quantity of vapor and a liquid, is in general somewhat similar to Type I, in that it employs counter-flow. It differs in providing a type of inlet suitable for the relatively large volume of the entering hot fluid, and, usually, in providing auxiliary points of entrance for the latter to the spiral section so as to compensate for condensation along the path and make the entire heat transfer surface effective.

Various ways of sealing the open ends of the spirals have been adopted. U-shaped packing strips of rubber held in place by steel bars rolled to fit the passages may be used, or the strips may be supported by flat steel covers. Flat material made to fit the ends of the spirals may also be held in place by rigid flat covers.

Tank Flange

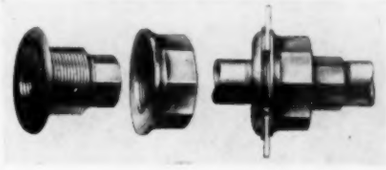
TO PERMIT connecting pipes to either the inside or outside of a tank (or both), American Pipe & Steel Corp., 230 Date Ave., Alhambra, Calif., has developed the new Unitank flange, a two-piece device which is inserted in a suitable hole cut in the tank wall, and made tight by means of a gasket within the tank. The manufacturer supplies a special Unitank flange cutter for cutting holes for flanges in metal up to 3/16 in. thick.

As will appear from the accompanying illustration, the flange body is tapped at both ends as well as on the outside. The outside tap employs a left-hand thread, corresponding with the thread in the nut. Thus, tightening the pipe connections to the flange tends to tighten rather than loosen the flange. These flanges are available in sizes from ½ to 8 in. One type of cutter is made for cutting holes for ½ to 1 in. flanges, while another type handles flange holes from 2 to 8 in. It is stated that a 6 in. flange can be installed in 3 min. using this cutter, and smaller sizes in less time.

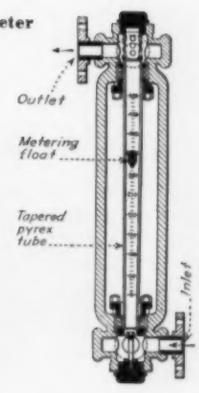
Universal Rotameter

SIXTEEN different connection arrangements can be made to the new universal rotameter which has recently been developed by Schutte & Koerting Co., Philadelphia, Pa. The pipe connections and frame of the instrument are in one piece, whereas the old style pillar type had eight pieces. This design is said to be extremely rigid, eliminating any strain on the tapered metering tube. The latter can be inserted and taken out of the frame without disconnecting the pipe line. This design is made in nine sizes, with connections ranging from ¼ in. to 2½ in. in diameter.

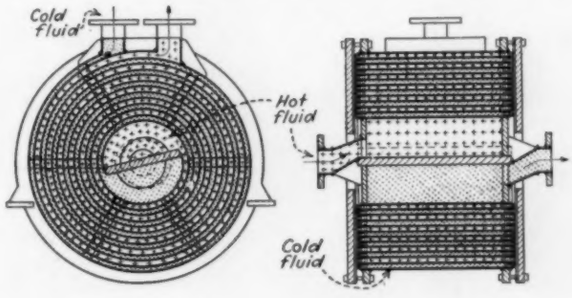
New Unitank flange



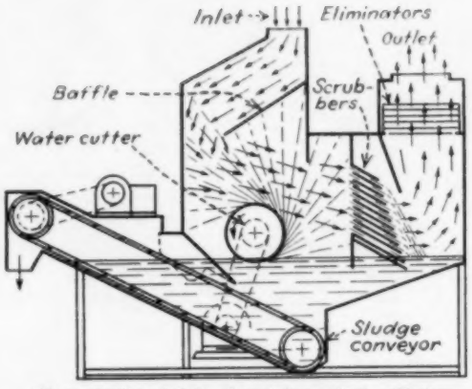
Universal rotameter



End and side sections of spiral heat exchanger



Cutaway view of new Coal Flow stoker for boilers to 300 hp.



Diagramatic sketch of wet type dust collector

Improved Stoker

FOR THE FIRING of industrial boilers in sizes up to 300 hp., the Iron Fireman Mfg. Co., Cleveland, Ohio, has developed the Coal Flow system which automatically handles coal direct from the bunker to the furnace. The principal design features of the new stoker are indicated in the accompanying cutaway view which shows the stoker to be of the underfired type in which a screw is used to propel coal from the bunker to the retort. Special agitators in the bunker, driven by the rotation of the screw, are available to assure movement of the coal if wet coal is used. The coal conveying section is built in lengths up to 20 ft. Automatic control of the air volume in the combustion zone is secured by special control. By use of a three-speed transmission, three feed screw speeds are available.

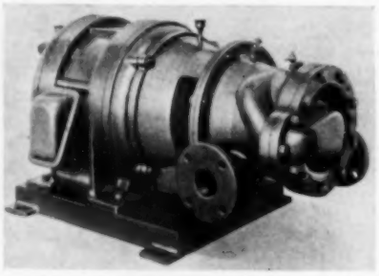
Two-Stage Pump

SUPPLEMENTING its line of single-stage close-coupled motor-driven pumps, the Allis-Chalmers Mfg. Co., Milwaukee, Wis., has added a two-stage pump of this type, good for heads up to 525 ft. at 3,550 r.p.m. This pump, employing what the company calls its "SSUnit" construction, is of the 2½-in. by 1½-in. size and has an efficient capacity range of from 50 to 100 c.f.m. against heads from 300 to 500 ft. The pump is available with motors of from 10 to 30 hp., of either flame-proof or explosion-proof construction. The standard pump has a cast iron casing and cover and is bronze fitted. The impellers are placed back to back to provide axial balance, with the suction impeller next to the motor and the discharge passage between stages cast integral with the main casing body in such a fashion as to permit the cover to be removed.

Wet Dust Collector

USE OF FOUR dust collecting stages within a single piece of apparatus is an important feature of the Centri-Merge dust collector, now being built under the Schmieg patent, by the W. W. Sly Mfg. Co., Cleveland, Ohio. As the dust laden air enters the inlet chamber (see diagramatic drawing), its direction is suddenly changed by a baffle, and it is also permitted to expand. Settling of the heavier particles is thus facilitated. From the inlet chamber, the air passes into a spray chamber with another change of direction and a second drop in velocity. Here a revolving water cutter fills the chamber with a dense spray which assists in knocking particles from the air stream. Leaving the spray chamber, the air, with any remaining dust, passes between a number of scrubber plates sloping downward from the spray chamber. Large quantities of water from the cutter flow through the scrubber openings with the air and dust so as to remove the remaining dust. Finally, from the scrubbers, the air passes upward through eliminators for removing the water and trapping any fine dust particles still remaining. As shown in the drawing, a conveyor is provided for removing sludge from the bottom of the settling tank.

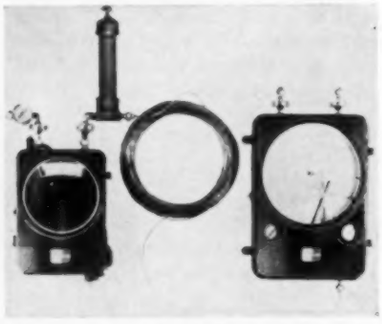
According to the manufacturer, the new equipment supplements the company's line of flat cloth bag filters in that it is particularly suitable for conditions of moisture, acid and extreme heat. Advantages claimed for the unit include the fact that it is self-contained, compact and requires no settling tank nor spray nozzles.



New "8S Unit" two-stage pump

Pneumatic Telemeter

THE BRISTOL CO., Waterbury, Conn., has recently supplemented its line of electrical telemetering equipment with a pneumatic telemetering system for recording and automatically controlling temperatures, flow, pressure and liquid level at a distance. The new instrument, known as the Metavane, was developed particularly for use in plants where explosive fumes are present. The Metavane consists of two instruments, a transmitter and a receiver. The transmitter measures the variable in question, indicates its value on a scale for the use of the operator and transmits the reading to the receiver which may be several hundred feet away. 15-lb. air provides power for operating the system.



Pneumatic telemetering equipment

New Products

BAKELITE CORP., 247 Park Ave., New York, N. Y., has announced production of cellulose-acetate molding materials in a wide range of colors, in opaque, translucent and transparent effects, as well as in mottled or variegated colors. These materials are made to the customer's requirements. They are thermo-plastic and suitable for either injection or compression molding. They are obtainable in various degrees of plasticity and with a considerable variation in other physical properties possible to suit requirements.

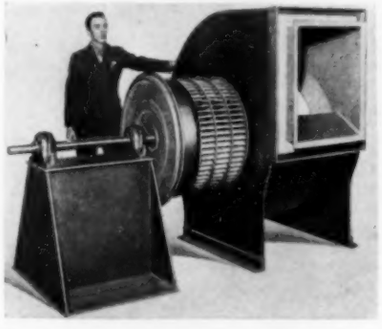
A NEW WIDE-RANGE test paper for the determination of hydrogen ion concentration has been introduced by R. P. Cargille, 118 Liberty St., New York, N. Y., under the name of Hydrion paper. These paper strips are used like litmus paper but give five color changes in the range from pH 2 to pH 10. Color changes are distinctive, ranging from bright red for

strong acids, through orange and yellow to green and finally blue for strongly alkaline solutions.

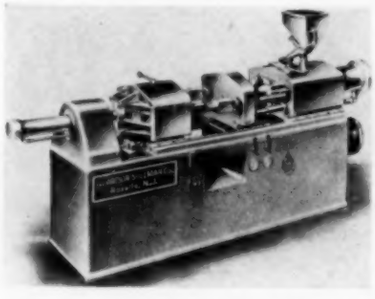
CATALIN CORP., 1 Park Ave., New York, N. Y., has developed and has for a period of three years been testing a new alcohol-soluble liquid phenolic resin glue for plywood lamination which has now been announced after successful termination of the tests. The new glue is said to make possible the economical production of an improved plywood with no deviation from methods of glue application that have been used in the past by the plywood industry. The gluing process is said to be greatly simplified and the time required for operation reduced to a minimum. The resultant bond is described as completely waterproof, mold-proof, fungi-proof and insect-proof. An advantage is that the plywood manufacturer is able easily and precisely to vary glue spreads for different species of wood. The new glue is stainless and is said to be suited to curved or bent work owing to the flexibility of the liquid resin bond.

A NEW SYSTEM of treatment for coloring and dustproofing concrete floors for factories, warehouses and other buildings has been announced by the Truscon Laboratories, Detroit, Mich., under the name of Flor-Dye. The new treatment is said not to form a surface film, but to penetrate, becoming an integral part of the cement surface. Hence it is stated not to wear off easily nor to peel, chip or crack. The new finish is oilproof and generally stainproof, sealing the pores and preventing absorption of most staining materials such as oil, grease and the like. The finish must be applied over clean concrete after complete removal of oil and old paint. Flor-Dye is then applied in two coats (generally) and after setting, Flor-Dye dressing is applied as a protective finish.

High-temperature insulated fan



Hydraulic automatic injection molding machine



Insulated Fans

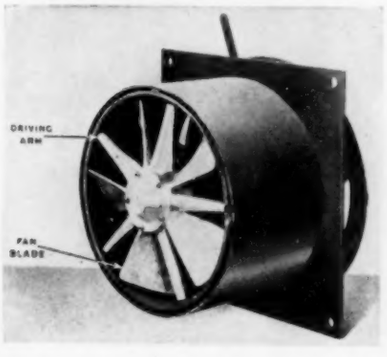
FOR SEVERE SERVICE at high temperatures the Industrial Gas Engineering Co., 201 East Ohio St., Chicago, Ill., has recently added the Type MIH Thermo Exhauster to its line of equipment. The housings are of double walled construction, the inner wall being of welded heat-resisting alloy plate and the outer wall of steel with 5 in. of heat insulation between. Wheels, also of heat-resisting alloys, may be removed from the housing without disturbing the insulation. Bearings are mounted on an independent base to minimize heat transmission. If desired, air-cooled ball bearings or water-cooled sleeve bearings may be secured. Three standard designs cover temperature ranges to 800, 1,000 and 1,400 deg. F., respectively. Capacities range from 1,000 to 60,000 c.f.m.

Rotary Gas Burner

WHAT IS SAID to be an entirely new principle in gas burner construction appears in the Coppus-Dennis Fanmix gas burner, recently announced by the Coppus Engineering Corp., Worcester, Mass. Earlier burners are stated to have been of either the venturi, the ring or the center-fired diffusion type. The new burner consists primarily of a fan with a long hub, mounted on ball bearings so that the fan rotates on a stationary shaft which serves at the same time as the gas inlet pipe. The fan has several air blades as well as a number of driving arms and the gas, entering the fan hub, leaves the driving arms through small orifices so that, by reaction, the gas flow causes the fan to rotate at high speed. The fan blades then act to deliver air for combustion so as to produce a thorough mixture of air and gas.

It is stated that this principle makes possible securing a definite ratio between air and gas and, further, that this ratio is substantially maintained at reduced gas flow. Owing to the quality of the mixture, it is possible to use a smaller combustion space, while unusually high efficiency, high and even furnace temperature, reduction of stack requirements and 100 per cent turn-down ratio are among the other claims. The new burner operates at pressures from 5 to 40 lb. gas pressure.

15-in. Coppus-Dennis gas burner



Injection Molding Machine

A COMPLETE, self-contained automatic injection molding machine, designated as the No. 6 Wasco, adapted for manual, semi-automatic or full-automatic operation, has been announced by the Watson-Stillman Co., Roselle, N. J. Dies 6 in. thick and up can be accommodated. It is stated that dies up to 50 sq. in. of projected area are held closely by a patented clamping device without transmitting strain to the rest of the machine. Large plasticizing capacity is claimed for the heating cylinder, without the need for excessive heat which may cause burns in material. The heating cylinder is capable of handling up to 50 lb. per hour, while the timing device may be set from 1 to 6 cycles per min.

Equipment Briefs

IN AN EFFORT to improve the already desirable characteristics of the U-bolt valve, Jenkins Bros., 80 White St., New York, N. Y., has developed new bronze-mounted and all-iron U-bolt gate valves which are said to possess many new features, among which is a renewable "bonnet-saver-bushing." This makes it unnecessary to junk the valve bonnet when the threads are worn. A new bushing is simply slipped into position in the old bonnet.

A NEW LINE of equipment for killing bacteria and preventing mold has been announced by the Lamp Division of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. The equipment makes use of selected ultra-violet radiations produced by so-called Sterilamps, operating according to the Rentschler-James process. The lamps which are in the form of rods, operate on the gaseous discharge principle in an atmosphere of inert gases and mercury vapor, with over 80 per cent of the radiant energy produced in the region of 2550 Angstroms, which type of radiation is said to provide the most effective bactericidal energy for the power consumed. A special type of power unit is provided, consisting of a transformer, relay and accessory equipment.

YEOMANS BROS. CO., 1433 Dayton St., Chicago, Ill., has announced recently an important improvement in its line of rotary air compressors and dry vacuum pumps, whereby a phenolic material has

been substituted for steel in the rotating blades. The composition blades are tough and hard, and yet enough softer than iron or steel so that the blade edges, running on the bore of the cylinder, are claimed not to wear either the bore or other parts of the housing or rotor due to blade contact. Both cylinder and blades are said to acquire a high glaze, resulting in a perfect seal and high efficiency. Compressors of this type were described on page 635 of the October, 1928, issue of *Chem. & Met.*

GLASS CLOTH anode bags, a new application for the glass fibers produced by the Corning Glass Works, have recently been announced by Hanson-Van Winkle-Munning Co., Matawan, N. J. These bags are intended chiefly as a means for keeping the solution clean in nickel plating and preventing the formation of imperfections in the coating. Previously muslin bags were employed but with the higher acid strengths of the plating solutions now in use, the glass cloth bag has become increasingly desirable.

EASY CLEANING is an important feature of the new double-blade laboratory mixer recently introduced by the Read Machinery Co., York, Pa. The new mixer is built with a removable outboard bearing support which allows the bowl end to slip off the agitators, thus making cleaning easy. A reversible motor is furnished and the mixer can be built with a steam or water jacket and a vacuum- or vapor-tight cover, if desired. Various materials of construction are available. A feature is the close laboratory prediction of commercial results said to be obtainable with this equipment.

FOR THE automatic recording and control of pH with the glass electrode, the Coleman Electric Co., 310 Madison St., Maywood, Ill., has introduced a new instrument comprising three compact units: an amplifier and cell chain housed together, a power pack and any one of several standard recorder controllers. Each unit is contained in a fume-proof case. The glass electrode permits continuous flow of the sample. The instrument is reported to be sensitive to approximately 0.02 pH and accurate to 0.05 pH. An automatic warning device is provided to signal if any part fails to function properly or if the process gets out of control.

RAYMOND PULVERIZER DIVISION of Combustion Engineering Co., 1302 North Branch St., Chicago, Ill., has announced the development of a small hammer-type pulverizer for test grinding operations in the production of a wide variety of powdered materials. This is a motor-driven unit, equipped with a hand-operated screw feeder and five different sizes of perforated screens to give a wide range of classification. The machine is said to be particularly adapted to the development of new products and to secure results capable of interpretation in terms of commercial production. Output sizes range from 20 mesh to fine powder.

SUITABLE for use with the glass, quinhydrone, hydrogen, or any other electrode system following the Nernst equation, a new pH meter has been introduced by Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. When used with the glass electrode system furnished or with a quinhydrone electrode, simply setting the temperature compensator adapts the entire pH scale to measurements at that temperature. It is reported that the instrument may be used with external circuits of much higher resistance than the 100 to 300 megohms of the glass electrode which is supplied with it. Special quartz insulation is used where necessary, while the design is said to permit unimpaired accuracy in atmospheres up to 95 per cent relative humidity.

APPROVAL of a new respirator for use in dusts presenting a silicosis hazard has been granted by the U. S. Bureau of Mines to the American Optical Co., Southbridge, Mass. The design is said to assure maximum comfort, owing to its compactness and light weight and to the fact that it does not obstruct the vision. Facial adjustments are said to be unnecessary. A filter area of 42 sq. in. has been provided, together with improved valves said to insure ease of in- and exhalation.

Remote Pressure Transmitter

FOR UTILIZATION where explosion hazards make the use of electrical transmitting equipment undesirable, the Ashcroft Gauge Division of Manning, Maxwell & Moore, Inc., Bridgeport, Conn., has developed a pneumatic transmitting gage, the Duragauge, which is stated to give quick, accurate remote pressure readings over distances up to 1,000 ft. The instrument employs a 10-in. etched dial with any standard graduations from 0–60 lb. to 0–10,000 lb. Operation is accomplished by a balanced relay of the non-bleed type, assuring minimum air consumption and exceptional capacity for use with long lines, according to the manufacturer.

Remote pressure indicator

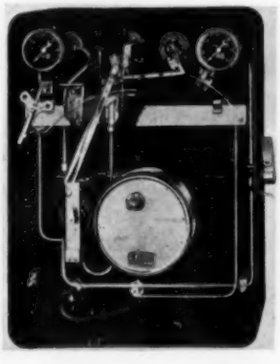
Foam-Liquid Pump

BINGHAM PUMP CO., Portland, Ore., has developed a centrifugal pump capable of handling foaming liquids by separating the foam or gas through an exhaust vent and delivering the liquid through the pump discharge in uninterrupted flow. The design of the new pump is said to prevent accumulation of foam or gas in the volute or impeller eye. The rotating element is the only moving part, the heavy-duty shaft being supported on wide-spaced oil-lubricated thrust and radial ball bearings. Labyrinth type deflector disks protect these bearings from oil leakage and from the entrance of foreign materials or moisture. Multiple packing rings are employed in the stuffing box. All parts of the pump are readily accessible and the impeller and casing easily inspected by removal of the suction piece. Through the use of suitable construction materials, the pumps are available for both acid and alkaline solutions, as well as liquids containing abrasive materials.

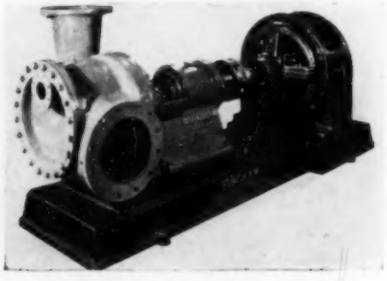
Improved Instruments

A RECENT ANNOUNCEMENT of the C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y., describes a new line of recorders and recorder-controllers with 10 and 12 in. charts for temperature

Mechanism of Tag throttling controller



New foam-liquid pump



and pressure. The recorders present new features of design including interchangeable calibrated tube systems which are readily replaceable and need checking at only one point. Other features include stainless steel pen arms, specially designed fountain pens, and a new pen arm movement of superior strength, lightness and rigidity. The same features appear in the recorder-controllers which are available in both "on-off" and throttling models. The former employs a simple, non-adjustable flapper and is designed for all ordinary temperature control applications. The throttling model utilizes an adjustable calibrated flapper stated to provide exact sensitivity adjustment for setting the throttling range to coincide with any considerable apparatus lag. For specially high lag, what is known as the "400" control unit is available for maintaining the predetermined control point within close limits, at the same time securing non-hunting control. This unit is said to operate by the employment of damped high sensitivity.

Shaking Screen

DESCRIBED as being capable of giving laboratory screening accuracy on a production basis, a new line of screens built in single and multi-deck designs, powered by the Ajax-Shaler Shaker has been announced by the Ajax Flexible Coupling Co., Westfield, N. Y. Both open and closed models, either level or pitched, are available. These screens, known as Vibroplane and Angleplane, are built in various construction materials as desired and are said to yield increased capacity per unit of floor area, to make possible extremely close separations, to eliminate abrasive action on the material being screened and to have unusually low power consumption. These screens employ a balanced drive to a deck mounted on substantially horizontal leaf springs. Uniformity of vibration of the entire screen surface is said to be assured. The drive mechanism is self-contained and fully inclosed, requiring only occasional oiling.

MANUFACTURERS' LATEST PUBLICATIONS

Alloys. International Nickel Co., Development and Research Division, 67 Wall St., New York City—Bulletin T-4—16 pages on methods for the fabrication of nickel-clad steel plate with information on forming and preparation of sheets, welding, joint design and applications.

Apparatus. Parr Instrument Co., Moline, Ill.—Manuel 117—41 pages completely describing construction and use of this company's oxygen bomb calorimeters and oxygen bomb sulphur apparatus, with details on calculation of results.

Chemicals. Interchemical Corp., 75 Varick St., New York City—16-page booklet entitled "The Story of Interrelated Research," briefly describing research activities of this company and its subsidiaries in the development of inks, chemical coatings, finishes and dyestuffs.

Dust Control. United States Hoffman Machinery Corp., Air Appliance Division, 105 Fourth Ave., New York City—Booklet A-303—8 pages on the control of industrial dust through the use of this company's portable heavy-duty vacuum cleaners.

Electrical Equipment. Roller-Smith Co., 233 Broadway, New York City—Catalog 6-b—Leaflet describing a new manhole-type oil circuit breaker for 200 to 600 amp., at 7,500 v.

Engines. Ingersoll-Rand Co., 11 Broadway, New York City—Form 10110—40-page bulletin on this company's Type S diesel engines, built in sizes from 3 to 8 cylinders and rated at 175 to 460 b.hp.

Equipment. Ingersoll-Rand Co., 11 Broadway, New York City—Form 2273-A—8-page bulletin describing this company's equipment for pulp and paper mills, including pumps, compressors, condensers, engines and other equipment.

Fans. National Association of Fan Manufacturers, 5-208 General Motors Bldg., Detroit, Mich.—Leaflet tabulating fair comparison charts of planing mill exhausters and cast iron volume fans for conveying materials, removing dust, and handling gases and fumes.

Feed Water Treatment. Ferrotect Industries, 719 Varsity Road, South Orange, N. J.—Bulletin covering this company's Corrosan process for boiler water treatment, also describing this company's products for protection of surfaces against water, corrosive materials and high temperatures.

Finishes. The Resinous Products & Chemical Co., 222 West Washington Sq., Philadelphia, Pa.—8-page booklet on Uformite urea-formaldehyde resins suitable for use in lacquers and enamels.

Floors. Snead & Co., 120 Pine St., Jersey City, N. J.—Bulletin describing this company's Armor Grids for the production of armored concrete and mastic floors for chemical plants.

Heaters. Carrier Corp., Syracuse, N. Y.—16-page bulletin completely covering this company's line of unit heaters with description, engineering data and diagrams of standard and special applications.

Heating Equipment. Industrial Gas Engineering Co., 201 East Ohio St., Chicago, Ill.—50-page loose-leaf catalog covering this company's gas- and oil-fired heating equipment for industrial processes and its high temperature blowers and exhausters; complete with engineering data.

Instruments. Askania Regulator Co., 1603 South Michigan Ave., Chicago, Ill.—12-page booklet completely illustrating and describing this company's equipment for automatic control of steam generating units.

Instruments. The Bristol Co., Waterbury, Conn.—Bulletin 511—16-page folder briefly explaining this company's system of coordinated process control and illustrating and briefly describing a considerable number of applications.

Instruments. The Foxboro Co., Foxboro, Mass.—Bulletin 227—8-page bulletin describing in detail construction, operation and application of this company's new remote pneumatic transmission system for measurement and control of flow, temperature, level and pressure.

Instruments. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.—Catalog E-33A (1)—12 pages giving detailed description of this company's Wenner thermocouple potentiometer for precise measurements of low voltages.

Instruments. Thwing-Albert Instrument Co., 3339-41 Lancaster Ave., Philadelphia, Pa.—Leaflet B-1138—2 pages describing this company's indicating radiation pyrometers.

Insulation. Quigley Co., 56 West 45th St., New York City—Bulletin 327-C—8 pages covering properties and applications of this company's Insulag, a refractory lagging for temperatures up to 2,200 deg. F.

Kettles. Patterson Foundry & Machine Co., East Liverpool, Ohio—4-page leaflet briefly describing this company's electrically heated kettles and showing advantages in comparison with other methods of kettle heating.

Materials Handling. Chain Belt Co., Milwaukee, Wis.—Bulletin 332—6 pages on the design and use of Rex apron conveyors.

Pipe. Republic Steel Corp., Cleveland, Ohio—Bulletin 316—10-page pamphlet with information on this company's standard pipe, copper-bearing steel pipe and Toncan copper-molybdenum-iron pipe, with bundling tables, sizes and weights, identification and corrosion information.

Piston Rings. C. Lee Cook Mfg. Co., Louisville, Ky.—Bulletin 385—6-page booklet announcing a new development in the manufacture of piston rings in which the wearing surfaces are electrically coated with a tin-base bearing alloy. Developed for automotive use, the new rings are also available for industrial engines, diesels and compressors.

Power Generation. Combustion Engineering Co., 200 Madison Ave., New York City—Catalog PC-5—34 pages describing this company's direct-fired systems for burning pulverized coal, with information on mills, burners, mill feeders, and furnaces.

Power Generation. Elgin Softener Corp., Elgin, Ill.—Bulletin 510—7 pages describing this company's continuous blowdown system for boilers.

Power Transmission. Chain Belt Co., Milwaukee, Wis.—Catalog 333—128 pages on this company's roller chains and sprockets, covering a wide variety of types with description, engineering data, information on corrosion resistance, tables of useful information; also prices.

Power Transmission. Palmer-Bee Co., Detroit, Mich.—48-page picture book illustrating this company's manufacturing facilities for power transmission and materials handling equipment, and steel fabrication.

Pumps. DeLaval Steam Turbine Co., Trenton, N. J.—Leaflet E-1171—7-page reprint of an A.S.M.E. paper on centrifugal pumps for handling liquids carrying solids in suspension, such as unscreened sewage and wood pulp in paper mills.

Pumps. Milton Roy, 2031 East Madison St., Philadelphia, Pa.—Bulletin 938—8 pages covering several improved models of single- and multiple-unit motor pump, designed for the pumping of chemicals against pressures to 15,000 lb. for treatment of water supplies, crude oil and similar purposes, and for proportioning.

Solenoid Valves. Automatic Switch Co., 154 Grand St., New York City—Loose-leaf catalog of bulletins covering a wide variety of types of solenoid operated valves for air, gas, steam and liquids, including shut-off valves, packless and packed valves, three- and four-way pilot valves.

Solenoid Valves. Davis Regulator Co., 2539 South Washtenaw Ave., Chicago, Ill.—Bulletin S-1—15 pages on this company's solenoid valves for general service on steam, air, gas and liquids, in a variety of designs and in sizes from ½ to 4 in.

Chemical Engineering NEWS

A. I. Ch. E. Returns to Birthplace for 31st Annual Meeting

RETURNING after a nine-year absence to Philadelphia, the city of its birth, the American Institute of Chemical Engineers held on November 9, 10 and 11 one of the most successful annual meetings in its history. Registered at official headquarters in the Benjamin Franklin Hotel were over 600 members and guests.

The election of officers this year brought no change in the Institute executive personnel, Fred C. Zeisberg, Webster N. Jones, Stephen L. Tyler, and C. R. DeLong being called upon to serve another term as president, vice-president, secretary and treasurer respectively. (See Fred C. Zeisberg note on this page.) On the board of directors, C. M. A. Stine, Victor L. King, J. LeRoy Bennett and Barnett F. Dodge were elected for terms of three years each to replace Edward Bartow, Gustav Egloff, Albert B. Newman and James G. Vail, whose terms expired with this meeting. Prof. D. B. Keyes was elected to complete the term of Ellery L. Wilson.

The meeting opened early Wednesday morning, November 9, with a welcome by Charles Bonine, president of the Engineers Club of Philadelphia and then swung immediately into the first technical session with a comprehensive paper by James G. Vail, chairman of the local committee on arrangements, describing chemical industry in the Philadelphia area. Dr. Frank B. Jewett of the American Telephone & Telegraph Co. then reviewed the influence of the patent system on American industry and in reply to recent attacks on the system pointed out that continuance of its basic concepts is vitally important to both industry and the public. Continuing along the line of economics, Dr. D. P. Morgan of Scudder, Stevens & Clark ably presented an analysis of the effects of business trends on chemical engineers and their jobs.

How feedwater treatments have contributed during the past 20 years to the increase in boiler evaporation rates from 150,000 to 1,000,000 lb. of steam per hour was the subject of a paper by E. P. Partridge of Hall Laboratories, Inc.

R. C. Gunness and J. G. Baker of Massachusetts Institute of Technology opened the second technical session Thursday morning with their paper on performance of perforated-plate distillation columns. They described a mash still of this type which attained an overall plate efficiency of 42 per cent. Evald Anderson of the Western Precipitation Corporation showed that suspended matter in gases can be closely estimated by the so-called metered volume filtration method.

The problem of stack losses from soda recovery furnaces in alkali pulp processes was discussed by H. S. Gardner of the University of Rochester and R. P. Whitney of Massachusetts Institute of Technology. For studying the flow of fluids through orifices it was shown by L. E. Stout and Grant Russell of Washington University (St. Louis) that the newer visual methods offer many advantages over pressure methods.

Two corrosion papers, one by H. L. Maxwell of du Pont on stainless steels for chemical equipment and the other by G. L. Cox of the International Nickel Co. on corrosion in the soap and fatty acid product industries, featured the final technical session on Friday. The use of a drilling compound rich in sodium silicate and sodium chloride to avoid "heaving" in oil drilling was described by C. L. Baker of the Philadelphia Quartz Company.

A paper by Dr. C. M. A. Stine and Chaplin Tyler of the du Pont Company, entitled "Training Tomorrow's Industrial Leaders" was the subject of much discussion. The authors advocated a new system of chemical engineering education whereby a student will be trained along lines of research, plant operation, or administrative engineering, depending on certain aptitudes revealed during the beginning of his course.

The last five papers comprised a symposium on heat transfer and covered particularly the subjects of boiling, condensation mechanism, and water and gas film coefficients.

Dr. Allen Rogers Dies After Long Illness

Dr. Allen Rogers, Emeritus Head of the Department of Chemical Engineering at Pratt Institute, died at his home in Hampden Highlands, Maine, on Nov. 4 after an extended illness. He is survived by his widow, a son and two grandsons.

Dr. Rogers was graduated from the University of Maine in 1897, and received his Ph.D. from the University of Pennsylvania in 1902. He was instructor in chemistry at the University of Maine from 1897 to 1900, and at the University of Pennsylvania until 1904. During 1904-05, Dr. Rogers was research chemist for the Oakes Mfg. Co. In 1905 he joined the faculty of Pratt Institute, and in 1920 was made head of the Department of Chemical Engineering and supervisor of that course. These positions he filled until illness forced his retirement a year ago.

Radasch Succeeds Newman At Cooper Union

Arthur H. Radasch has been appointed head of the department of chemical engineering at Cooper Union. He succeeds Dr. Albert B. Newman, who resigned to become head of the chemical engineering department of the College of the City of New York. Professor Radasch, who since 1927 has been associated with the research and development division of the Barrett Co., is known for his design of new processes and equipment. He has been active in supervising the construction and operation of new plants, and in making field surveys of plant operations and economic analyses of chemical processes. He has been identified with practically all of the unit operations of chemical engineering.

ARTHUR H. RADASCH

Fred C. Zeisberg Dies

The sudden death of Fred C. Zeisberg, president of the American Institute of Chemical Engineers, from heart disease on Nov. 12 came as a shock to his friends and to members of the Institute who had seen him in excellent spirits just the day before at the 31st Annual Meeting in Philadelphia. He had been re-elected president of the Institute on Nov. 9.

Mr. Zeisberg had been a special investigator in the development department of E. I. du Pont de Nemours & Co., Wilmington, Del., since 1927. He first came to the company in 1909 after graduating from the University of Virginia and serving a year with the Mathieson Alkali Works.

CHEMICAL preparedness, as such, is likely to be a small part of the total job of chemical process industry as Washington now develops its international problems. But there is no mistaking the fact that preparedness is the big economic and business problem that will have entirely new aspects during the coming winter.

Many of the plans for industrial preparation of the nation to meet any future military contingency tie back into chemical raw materials. This does not necessarily mean immediate big spending for all of these kinds of goods. But the reserve stocks of material will be increased and the manufacture of military equipment will be speeded up. Hardly one of these efforts does not root in some phase of chemical supply or chemical process industry material.

Even the power program which is having the President's particular attention finds much of its stimulus in the feeling that a sudden boom in business, either for peace-time or war-time, would develop shortages of electric energy for the manufacture of electrochemical and electrometallurgical products. That story, presented at some length in *Chem. and Met.* (September, pages 462-471) is one of the preparedness bottlenecks.

Wage-Hour Rulings

Perhaps most significant of all wage-hour rulings for chemical process industry are the decisions of Administrator Andrews about executives and professional workers. In most other cases rulings do not affect any large or important group since both wage rates and times of work are usually well within the new limits of 25 cents per hour and 44 hours per week.

One problem which will require careful analysis by chemical executives is that of technical employees, such as chemical engineers, chemists, and other research workers. These men are undoubtedly employed in a bona fide professional capacity. It seems likely, therefore, that there is no serious difficulty with respect to occasional work beyond 44 hours per week. To qualify for exemption from that limit, the Administrator states that such men must be "customarily and regularly engaged in work"—

predominantly intellectual and varied in character as opposed to routine mental, manual, mechanical or physical work, and

requiring the consistent exercise of discretion and judgment both as to the manner and time of performance, as opposed to work subject to active direction and supervision, and

of such a character that the output produced or the result accomplished cannot be standardized in relation to a given period of time, and

based upon educational training in a specially organized body of knowledge as distinguished from a general academic education and from an apprenticeship and from training in the performance of routine mental, manual, mechanical or physical processes in accordance with a previously indicated or standardized formula, plan or procedure, and

who does no substantial amount of work of the same nature as that performed by non-exempt employees of the employer.

NEWS FROM WASHINGTON

Washington News Bureau
McGraw-Hill Publishing Co.
Paul Wooton, Chief

Equipment Limits

The limit on speed for further power development is now discovered by officials to be in the shops which build turbines, generators, boilers, and the rest of hydroelectric and steam-electric power equipment. An equally intimate study of chemical process industry would probably disclose also for this division of business that the making of the machinery with which to make the chemicals is the limit which will determine maximum speeds for expansion of chemical process industry of almost all types. This is a point which process industry may need to investigate privately, either with or without government cooperation.

News "Fines"

Chemical Trucking — Any agency demonstrably subject to I.C.C. rules for the trucking of goods as a part of interstate movement is likely to be required to keep very elaborate records and make frequent reports to the Commission. Manufacturing Chemists Association is pressing its case with the I.C.C. in the hope that a mass of detailed work may not be imposed on owners of private trucks simply because these vehicles are used in a small measure under the requirements of the Motor Vehicle Act which is administered by I.C.C. Exemption for small carriers by water and small income pipeline carriers shows that the Commission does not intend to impose as great detail on small enterprises as on big systems. But use of gross income as an index of exemption would not be significant unless merely the value of the trucking were taken as a gage.

Glass Patents—Among the earliest technical investigations planned by the Temporary National Economic Committee (monopoly committee) is a study of the effect of the pooling of certain glass making patents. One keen Washington observer says "This patent pool has worked too well." It seems to make this unit of process industry an important first target. Other like patent projects may expect investigation later.

Quantity Discounts—Federal Trade Commission is undertaking to forbid giving of discounts based solely on the dollar value of annual purchases. It is claimed that such measure is not a proper index of the benefit to a selling company since a large purchaser with many small orders may be just as costly to serve as the small customer. Chemical marketers would come under this limitation if F.T.C. succeeds in applying its reasoning, initially directed against padlock marketing.

Agricultural Reorganization—Extensive changes in the organization of the Department of Agriculture are bringing together much of the technology formerly in various bureaus under the administrative direction of Dr. Henry G. Knight, chief of the Bureau of Chemistry and Soils. A warm controversy has grown up as to whether the new agency should be called "Bureau of Agricultural Technology". Spokesmen for chemical groups oppose this, desiring to retain the name "Chemistry" in the title of the enlarged bureau. They argue for "Bureau of Chemistry and Engineering". The soils work of the Department (but not the fertilizer investigations) is now under the Bureau of Plant Industry.

Two-Price Food—Secretary Wallace's proposal to give lower priced agricultural materials to the poor of the United States at reduced rates involves many technical, as well as economic, complications. It raises a more basic issue in which process industry is deeply concerned. For example, would it not be possible to market certain products like corn or sweet potatoes at a lower special price if they were going to be processed into non-food industrial materials? That, it is argued, would give possibilities of great new markets not available if ordinary prices must be paid for the raw materials of processing.

Bonneville Power—The only contract for sale of energy by the Bonneville Project Authority announced up to early November was for temporary distribution through the Northwestern Electric Co. It is expected, however, that shortly the Bonneville management will announce a contract under which electricity will be supplied for making chlorate weed killers.

GERMANY DEVELOPS USE OF ALUMINUM, COBALT, AND VANADIUM AS ALLOY METALS

From Our German Correspondent

LIGHTER-THAN-AIR development, as far as Germany is concerned, did not end with the tragic "Hindenburg" disaster at Lakehurst. The new LZ-130, recently christened "Graf Zeppelin," which was nearly finished when the "Hindenburg" crashed, was redesigned and has just completed successful "shakedown" flights around Friedrichshafen. The new ship embodies features which result in quieter operation and include ballast water recovery apparatus in the form of condensors attached to the four diesel engines. Additional safety precautions have been taken to prevent the escape and possible explosion of gases within the ship. German chemists are still experimenting to find some way to make non-flammable hydrogen mixtures but so far with little success.

The German State Railways, as well as the army, are acting as proving ground for many new materials, including new paints and varnishes and metals. One of the latest materials to withstand severe tests on streamlined trains has been a German substitute for imported asbestos. It consists of aluminum wool with a binding material of beet sugar treated with persulfates.

Aluminum is considered a domestically abundant metal and is widely used as a substitute material. A recent decree aimed to cut down the use of lead and tin, provides for gradually changing over to aluminum in the manufacture of all tubes for tooth pastes, cosmetics, etc. To economize in the use of aluminum for this purpose, the decree provides that the tubes will be made only in normed sizes. More important, however, has been the recent development of a 99.99 per cent "purest" aluminum, which is more resistant to acids, alkalis, gases, and salt water than the former 99.5 per cent pure aluminum. The improved metal has 65 per cent of the conductivity of copper, is softer than the previous aluminum and hence more adaptable as a packing material, and to increase corrosion resistance of other metals. It may be sprayed on in coats the thickness of .1 mm. In the manufacture of coatings for conduit cables, the new aluminum is more satisfactory than lead because of its firmness and light weight.

Much progress has also been made of late with aluminum alloys. Through a new plating process, for instance, it has become possible to make the strong duralumin alloy salt water resistant. In automobile production, chrome plating may give way to hydronalium, a new light metal alloy of aluminum and magnesium, which is applied by spraying and is claimed to be more satisfactory than chrome- and nickel-plating.

In fine steel production, cobalt and vanadium are finding increased use as alloy metals. The richest vanadium deposits in the world are said to be in Abenab in English-mandated German Southwest Africa, which is, incidentally, one of the many reasons why Germany is casting her eye on this former colony. In the Erzgebirge (Ore Mts.) in the part of Germany adjoining Czechoslovakia, attempts are being made to extract this ore domestically. It is hoped to cover a larger part of Germany's yearly import requirements of 15,000 tons of vanadium when more of the South German "dogger" ores are processed.

New Chemical Engineering Building for V.P.I.

The chemical engineering department of Virginia Polytechnic Institute, Blacksburg, Va., moved into a brand new 3-story stone building all its own this fall. Included in the 11,416 sq. ft. of floor space are a unit operations laboratory, project development laboratory, library, three research laboratories, seven classrooms and four offices.

More than a quarter of the total space is occupied by the unit operations laboratory, which extends 31 ft. up through the three floors of the building. Among the pieces of processing equipment provided are an 18-in. Sperry plate and frame filter press; 24-in. vacuum filter; FEinc continuous filter; 500-gal. sedimentation system; still and fractionating column; batch vacuum still; stone ware absorption tower; heat exchanger with fluid flow assembly; triple-effect evaporator including horizontal tube, vertical tube and long tube forced circulation effects; atmospheric and vacuum tray dryers; vacuum double-drum dryer; 26-in. basket centrifugal; super-centrifuge; vacuum impregnator; water softener; reaction and mixing kettles; electric furnaces; Hytor compressors; crystallization pans; and a 3-roll compounding mill. One corner of the laboratory is completely closed off for grinding equipment and houses a ball mill, hammer mill, disk mill, jaw crusher, shaking machine, and a Williams roller mill.

With its new array of laboratory equipment and increased classroom facilities, V.P.I. becomes one of the best equipped schools for chemical engineering instruction in the South.

New Fiber Glass Developed By Glass Companies

Owens-Illinois Glass Co. and Corning Glass Works have formed the Owens-Corning Fiberglas Corp. which will produce a variety of products from fiber glass. This marks the culmination of development work by the two companies involving expenditures of about $5,000,000. Consuming outlets will be sought in such fields as household equipment, construction, electrical power, and refrigeration insulation. Amory Houghton, president of Corning Glass Works, is chairman of the board of the new corporation. Harold Boeschenstein has resigned as vice-president and general manager of Owens-Illinois Glass Co. to become president and other officers are Games Slayter, vice-president; W. P. Zimmerman, vice-president in charge of manufacturing and sales; G. E. Gregory, general sales manager; A. C. Freligh, secretary; H. R. Winkle, comptroller. Principal offices will be in Toledo. Production already has started at plants in Newark, Ohio and Corning, N. Y.

New building houses chemical engineering department of Virginia Polytechnic Institute.

Chemical ECONOMICS and MARKETS

CHEMICAL-CONSUMING INDUSTRIES CONTINUE TO MOVE UPWARD

LATEST figures covering industrial operations show the war scare had some effect in slowing up the rate of acceleration of activities but the trend has continued progressively upward from July forward with October making a better showing than any preceding month of the year. The *Chem. & Met.* preliminary index for chemical consumption for October is 108, which compares with a revised index of 105.71 for September.

The rise in consumption of raw materials in September was very moderate. Glass production was spotty with the output of window glass rising to 522,145 boxes compared with 433,871 boxes in the preceding month. Plate glass and glassware production also was higher but the important branch of glass containers fell below the August level. Textile plants took on smaller lots of cotton and wool. Coal products failed to advance in proportion to the rise at iron and steel works.

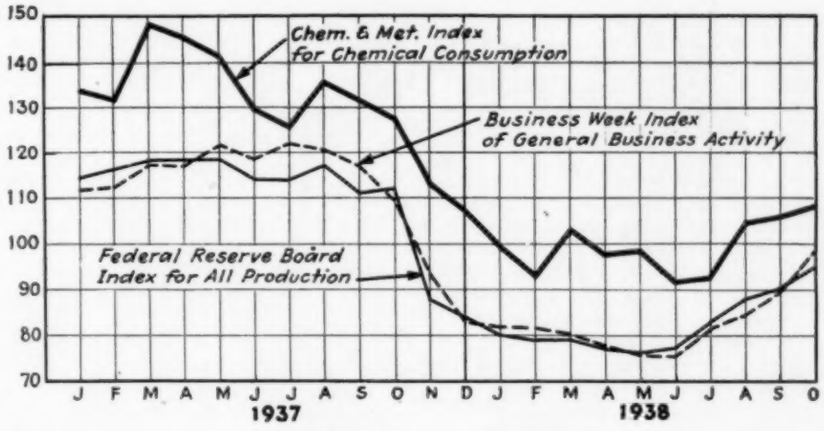
***Chem. & Met.* Index for Consumption of Chemicals**

	August (Revised)	September
Fertilizer	22.35	21.96
Pulp and Paper	13.90	14.20
Glass	9.30	9.34
Petroleum refining	13.23	12.80
Paint and Varnish	10.71	11.06
Iron and Steel	5.96	6.55
Rayon	5.22	5.15
Textiles	7.16	6.83
Coal products	4.95	5.43
Leather, Glue and Gelatine	4.31	4.31
Explosives	4.04	4.44
Rubber	2.09	2.14
Plastics	1.44	1.50
	104.66	105.71

In October, the larger call for raw materials was well distributed among the various consuming industries but mill takings of silk were disappointing as they fell considerably below trade estimates.

Considering the business situation generally, there appears to be sufficient reason for confidence in continued improvement with the usual allowance for seasonal influences in individual cases. Primarily, these reasons rest upon the widening effect of government purchasing with the consequent following of a rising national income. One prominent economist places the national income in October at about 10 per cent below that for October last year and projecting into the spring of next year, establishes a level about 8 per cent over the comparable period of last spring. This statement, likewise is based on the stimulus of government expenditures and particularly on the figures for planned construction which would indicate that total construction contracts for the first half of 1939 will run from 30 to 40 per cent in excess of those for the first six months of 1937 which was an active construction period. Apart from any controversy regarding the economic soundness of the government action, the fact remains that plans for huge expenditures have been adopted; that raw materials of various kinds, equipment, etc., will be bought in large volume and the national income or purchasing power will be lifted appreciably for a period to cover at least the first six months of next year.

The monthly index of general business activity compiled by *Business Week* rose to 98.5 in October as compared with 89.8 in September. This index has moved up steadily from July forward. The Federal Reserve Board index for industrial production was advanced to 95 for October from 90 in September. The Board reported that production of automobiles during the latter part of this year is running at about the same level as in the corresponding period of 1935. Related products such as plate glass and tires are being produced in somewhat larger volume, but the rate is still much below the 1937 high levels.



On a seasonally adjusted basis, the value of contracts let for residential construction in August and September was close to the highest level since the end of 1929.

According to the Reserve Board's report, construction had been started on 40 per cent of the PWA program, or on non-federal projects to cost $510,000,000 and on federal projects with a value of $190,000,000.

Production and Consumption Data for Chemical-Consuming Industries

	Sept. 1938	Sept. 1937	Jan.-Sept. 1938	Jan.-Sept. 1937	Per cent of decline for 1938
Production					
Alcohol, ethyl, 1000 pr. gal	15,800	17,219	143,675	161,111	10.8
Alcohol, denatured, 1000 wi. gal	9,181	11,513	61,171	67,889	11.0
Benzol, 1000 gal	6,056	10,765	48,841	93,592	47.8
Byproduct coke, 1000 tons	2,675	4,426	22,063	39,115	43.6
Glass containers, 1000 gr.	3,653	4,548	28,508	36,300	21.5
Plate glass, 1000 sq. ft	8,873	16,479	47,282	156,300	69.9
Nitrocellulose plastics, 1000 lb	974	1,506	6,630	14,770	55.1
Cellulose acetate plastics, 1000 lb	592	1,224	3,442	10,909	68.4
Rubber reclaimed, tons	12,016	16,410	72,422	139,702	48.0
Sulphuric acid (fertilizer) tons	133,266	188,252	1,267,605	1,594,655	20.5
Superphosphate, tons	288,364	358,207	2,708,733	3,295,981	17.8
Consumption					
Cotton, bales	534,037	601,305	4,200,981	5,978,499	29.7
Silk, bales	38,844	36,372	299,360	335,566	11.9
Wool, scoured, 1000 lb	26,005	24,563	180,813	305,331	40.8
Explosives, 1000 lb	30,443	34,310	230,338	294,586	21.8
Rubber, crude, tons	37,823	43,893	279,546	439,491	36.4
Sulphuric acid (fertilizer) tons	126,974	144,273	1,081,387	1,420,510	23.8

CONTRACT COMMITMENTS HOLD CHIEF INTEREST IN MARKET FOR CHEMICALS

PRODUCERS of many of the more important chemicals have announced readiness to accept contracts for delivery over next year. In the majority of cases the new contract prices are merely an extension of those which were in effect on 1938 deliveries. Among the commodities for which new prices will prevail are sulphur and carbon black. Producers of sulphur, who had maintained an unchanged price level for many years, announced a reduction of $2 a ton, making the price $16 a ton f.o.b. mines. On the other hand, the low prices quoted for carbon black last year have been revised upward and this material is now held at 2¾¢ per lb. No change was announced for the export schedule.

Withdrawals of chemicals have held up to the increased levels of recent weeks with various consuming industries in a more active position. The main interest, however, has centered in contract placements and forward business is reported to have run into large volume. Consumption is generally regarded as pointing to a higher total for the first quarter of next year as compared with the like period of 1938.

With the exception of sulphur and carbon gas black, price changes for chemicals have not been important but competition is still keen especially in the case of some of the solvents, and this gives an unsettled tone to those selections. The fact that contract prices for so many chemicals have been continued is assurance that no widespread price changes are in prospect.

Values for vegetable oils have eased off during the month. The trend was fairly general but China wood oil moved up sharply for a time because of fears that stocks would not be able to be moved from primary points. There still is no assurance of regular shipments from China but prices have receded from the high point and with ample stocks on hand, buyers are content to await developments before worrying about covering future requirements.

Production of methanol followed a seasonal course in September with antifreeze requirements gaining importance. Production of crude methanol in that month amounted to 303,225 gal. which brought production for the nine months up to 3,133,139 gal. compared with 4,444,949 gal. for the like period of last year. Producers of synthetic methanol turned out 1,929,655 gal. in September with 18,274,409 gal. as the nine-month total as against 20,831,842 gal. for last year.

Sales of paint, varnish and lacquer in September as reported by 680 establishments reached a value of $31,046,584, which represents a moderate increase over the figure for August and a drop from the $34,489,882 reported for September, 1937. Sales of lacquer in the third quarter of this year were 8,333,092 gal. and 12,135,940 gal. for the third quarter of 1937.

Increased domestic production of casein is cutting down importations from the Argentine and other countries. Last year the home output reached an all-time peak of 67,467,000 lb. Imports declined and for the first eight months of this year, imports amounted to only 239,684 lb., indicating domestic casein has captured practically all of the home market.

A report from our commercial attache at Buenos Aires says that the 1937 report of the Argentine Ministry of Public Works shows that the "Obras Publicas" (Sanitary Works Department) produced 16,885 metric tons of 55° Baume sulphuric acid in 1937, utilizing 3,954 tons of sulphur and 87 tons of sodium nitrate. This agency's production of sulphuric acid was 22,284 tons in 1936, 16,934 in 1935, and 20,945 in 1934.

The "Obras Sanitarias" water purification activities included also production of 12,986 tons of coagulant (aluminoferric), utilizing 24,434 tons of "loess" (mineral earth) and 10,031 tons of sulphuric acid. Furthermore, the "Dusi" type of aluminum sulphate was produced in both liquid and solid; 3,112 tons of bauxite and 7,286 tons of sulphuric acid were used to produce 9,835 tons of the liquid, while 464 tons of the solid were produced from 172 tons of bauxite and 412 tons of sulphuric acid.

Effective in September 1937, the domestic aluminoferric coagulant (from "loess") was substituted by the bauxite coagulant. Experiments showed that imported aluminum sulphate was found to be 14.5 per cent more efficient than the bauxite coagulant of domestic make, and 25.45 per cent more efficient than the "loess" coagulant, thus giving the bauxite coagulant a 10.95 per cent advantage over the "loess" product.

Apparently the "Obras Sanitarias" will continue with the local manufacture of coagulant from Brazilian bauxite. A Government decree dated September 30, 1937 and printed in the "Boletin Official" under date of August 26, 1938, states that although the 20,018 tons of Brazilian bauxite obtained under the contract of August 28, 1936, is sufficient to produce aluminum sulphate for use up to August 1940, it is thought advisable to exercise the option of purchasing 24,000 additional tons, to be delivered between October 1938 and May 1939.

From Germany comes the report that in view of the steadily growing use of plastics in Germany, a new school which will specialize in the manufacturing technique of the new synthetic materials will be inaugurated at Halle, Saale. The institution will be the first of its kind in Germany and will bear the name of "Hohere Technische Lehrenstalt fur Werkstofftechnik (technical School for Plastics Technic). A new type of engineers will be trained there with a view to subsequent specialization in the various technics of manufacturing plastics. Each course will comprise 5 semesters and students will be required to have had sufficiently practical training in factories and workshops before entering the school. The establishment consists of 200 rooms for theoretical and practical training of the pupils along the lines of the "Four Year Plan." It is contemplated that the school will be ultimately extended to the rank of a technical college.

In Italy a Ministerial Decree of August 10, 1938, published in the Official Gazette of Sept. 19, prohibits the use of benzol and homologous products as a carburant. Coking, gas and tar distillation plants are required to submit to fractional distillation their entire production of crude light oils in order to recover pure and refined benzol, toluol and xylol.

CHEM. & MET.

Weighted Index of

CHEMICAL PRICES

Base=100 for 1935

This month	**99.00**
Last month	99.47
November, 1937	101.91
November, 1936	98.17

Business in sulphur was going through at the reduced price. Sulphate of ammonia was automatically moved up for November delivery. Copper sulphate was fractionally higher. Solvents were irregular with a recovery for turpentine and an easy price tone for some other selections.

CHEM. & MET.

Weighted Index of Prices for

OILS AND FATS

Base=100 for 1935

This month	**75.19**
Last month	77.01
November, 1937	91.40
November, 1936	101.29

China wood oil closed above last month's figure but practically all the other oils were reduced in prices. Soybean oil is giving more competition in the edible field with a larger production on prospect. All grades of glycerine were lowered in price.

Current PRICES

INDUSTRIAL CHEMICALS

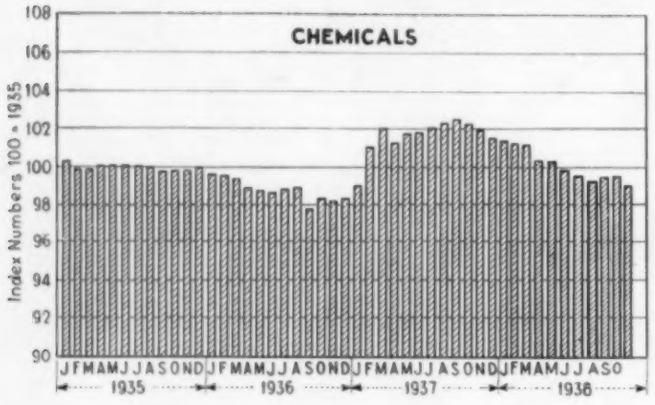
	Current Price	Last Month	Last Year
Acetone, drums, lb.	$0.05½–$0.06½	$0.05½–$0.06½	$0.06 –$0.07
Acid, acetic, 28%, bbl., cwt.	2.23 – 2.48	2.23 – 2.48	2.38 – 2.63
Glacial 99%, drums	8.43 – 8.68	8.43 – 8.68	8.43 – 8.68
U. S. P. reagent	10.25 –10.50	10.25 –10.50	10.25 –10.50
Boric, bbl., ton	106.00–111.00	106.00–111.00	105.00–115.00
Citric, kegs, lb.	.23½– .25	.23½– .25	.24 – .27
Formic, bbl., ton	.10½– .11	.10½– .11	.10½– .11
Gallic, tech., bbl., lb.	.70 – .75	.70 – .75	.75 – .78
Hydrofluoric 30% carb., lb.	.07 – .07½	.07 – .07½	.07 – .07½
Lactic, 44%, tech., light, bbl., lb.	.06½– .06½	.06½– .06½	.6½ – .6½
Muriatic, 18°, tanks, cwt.	1.05 –.....	1.05 –.....	1.05 –.....
Nitric, 36°, carboys, lb.	.05 – .05½	.05 – .05½	.05 – .05½
Oleum, tanks, wks., ton	18.50 –20.00	18.50 –.....	18.50 –20.00
Oxalic, crystals, bbl., lb.	.10½– .12	.10½– .12	.10½– .12
Phosphoric, tech., c'bys., lb.	.09 – .10	.09 – .10	.09 – .10
Sulphuric, 60°, tanks, ton	13.00 –.....	13.00 –.....	13.00 –.....
Sulphuric, 66°, tanks, ton	16.50 –.....	16.50 –.....	16.50 –.....
Tannic, tech., bbl., lb.	.40 – .45	.40 – .45	.40 – .45
Tartaric, powd., bbl., lb.	.27½–	.27½–.....	.24½–.....
Tungstic, bbl., lb.	2.75 –.....	2.75 –.....	2.75 –.....
Alcohol, Amyl	–	–	–
From Pentane, tanks, lb.	.106–.....	.106–.....	.123–.....
Alcohol, Butyl, tanks, lb.	.08½–.....	.08½–.....	.08½–.....
Alcohol, Ethyl, 190p'f., bbl., gal.	4.61½–.....	4.61½–.....	4.14 –.....
Denatured, 190 proof			
No. 1 special, dr., gal wks.	.30 –.....	.30 –.....	.34 –.....
Alum, ammonia, lump, bbl., lb.	.03½– .04	.03½– .04	.03 – .04
Potash, lump, bbl., lb.	.03½– .04	.03½– .04	.03½– .04
Aluminum sulphate, com bags cwt.	1.15 – 1.40	1.15 – 1.40	1.35 – 1.50
Iron free, bg., cwt.	1.30 – 1.55	1.30 – 1.55	2.00 – 2.25
Aqua ammonia, 26°, drums, lb.	.02 – .03	.02 – .03	.02½– .03
tanks, lb.	.02 – .02½	.02 – .02½	.02½– .02½
Ammonia, anhydrous, cyl., lb.	.15½–.....	.15½–.....	.15½– .16
tanks, lb.	.04½–.....	.04½–.....	.04½–.....
Ammonium carbonate, powd tech., casks, lb.	.08 – .12	.08 – .12	.08 – .12
Sulphate, wks., cwt.	1.375–	1.3625–.....	1.40 –.....
Amylacetate tech., tanks, lb.	.09½ –.....	.09½– .12	.11 – .11½
Antimony Oxide, bbl., lb.	.11½– .12	.11½– .12	.15½– .16
Arsenic, white, powd., bbl., lb.	.03 – .03½	.03 – .03½	.03– .03½
Red, powd., kegs, lb.	.15½– .16	.15½– .16	.15½– .16
Barium carbonate, bbl., ton	52.50 –57.50	52.50 –57.50	52.50 –57.50
Chloride, bbl., ton	79.00 –81.00	79.00 –81.00	79.00 –81.00
Nitrate, cask, lb.	.07 – .08	.07 – .08	.07 – .08
Blanc fixe, dry, bbl., lb.	.03½– .04	.03½– .04	.03½– .04
Bleaching powder, f. o b., wks., drums, cwt.	2.00 – 2.10	2.00 – 2.10	2.00 – 2.10
Borax, gran., bags, ton	48.00 –51.00	48.00 –51.00	46.00 –51.00
Bromine, cs., lb.	.30 – .32	.30 – .32	.36 – .38
Calcium acetate, bags	1.65 –.....	1.65 –.....	1.95 –.....
Arsenate, dr., lb.	.06½– .07	.06½– .07	.06½– .07
Carbide drums, lb.	.05 – .06	.05 – .06	.05 – .06
Chloride, fused, dr., del., ton	21.50 –24.50	21.50 –24.50	20.00 –33.00
flake, dr., del., ton	23.00 –25.00	23.00 –25.00	22.00 –35.00
Phosphate, bbl., lb.	.07½– .08	.07½– .08	.07½– .08
Carbon bisulphide, drums, lb.	.05 – .06	.05 – .06	.05 – .06
Tetrachloride drums, lb.	.04½– .05½	.04½– .05½	.05½– .06
Chlorine, liquid, tanks, wks., lb.	2.15 –.....	2.15 –.....	2.15 –.....
Cylinders	.05½– .06	.05½– .06	.05½– .06
Cobalt oxide, cans, lb.	1.67 – 1.70	1.67 – 1.70	1.67 – 1.70
Copperas, bgs., f.o.b., wks., ton	15.00 –16.00	15.00 –16.00	15.00 –16.00
Copper carbonate, bbl., lb.	.10 – 16½	.10 – 16½	.09 – .16
Sulphate, bbl., cwt.	4.50– 4.75	4.40 – 4.65	4.75 – 5.00
Cream of tartar, bbl., lb.	.22½– .23	.22½– .23	.19½– .20
Diethylene glycol, dr., lb.	.22 – .23	.22 – .23	.22 – .23
Epsom salt, dom., tech., bbl., cwt.	1.80 – 2.00	1.80 – 2.00	1.80 – 2.00
Ethyl acetate, drums, lb.	.06½–.....	.06½–.....	.07½–.....
Formaldehyde, 40%, bbl., lb.	.05½– .06½	.05½– .06½	.05½– .6½
Furfural, dr., lb	.10 – .17½	.10 – .17½	.10 – .17½
Fusel oil, ref. drums, lb.	.12½– .14	.12½– .14	.16 – .18
Glaubers salt, bags, cwt.	.95 – 1.00	.95 – 1.00	.95 – 1.00
Glycerine, c.p., drums, extra, lb.	.14½–.....	.16½–.....	.21½–.....
Lead:			
White, basic carbonate, dry casks, lb.	.06½–.....	.06½–.....	.07½–.....
White, basic sulphate, sck., lb.	.06 –.....	.06 –.....	.07½–.....
Red, dry, sck, lb.	.08 –.....	.08 –.....	.07½–.....
Lead acetate, white crys., bbl., lb.	.10 – .11	.10 – .11	.12 – .13
Lead arsenate, powd., bbl., lb.	.11 – .11½	.11 – 11½	.11½– .12
Lime, chem., bulk, ton	8.50 –.....	8.50 –.....	8.50 –.....
Litharge, pwd., csk., lb.	.066–.....	.066–.....	.07½–.....
Lithophone, bags, lb.	.04½– .04½	.04½– .04½	.04½– .05
Magnesium carb., tech., bags, lb.	.14½– .06½	.06 – .06½	.06 – .06½
Methanol, 95%, tanks, gal.	.31 –.....	.31 –.....	.31 –.....
97%, tanks, gal.	.32 –.....	.32 –.....	.32 –.....
Synthetic, tanks, gal.	.33 –.....	.33 –.....	.33 –.....
Nickel salt, double, bbl., lb.	.13 – .13½	.13 – .13½	.13 – .13½
Orange mineral, csk., lb.	.10½–.....	.10½–.....	.10½–.....
Phosphorus, red, cases, lb.	.40 – .42	.40 – .42	.40 – .42
Yellow, cases, lb.	.24 – .30	.24 – .30	.24 – .30
Potassium bichromate, casks, lb.	.08½– .09	.08½– .09	.08½– .09
Carbonate, 80–85%, calc. csk., lb.	.05½– .06	.05½– .06	.–06½ .07
Chlorate, powd., lb.	.09½–.....	.09½–.....	.09½– ....
Hydroxide (c'stic potash) dr., lb.	.07 – .07½	.07 – .07½	.07 – .07½
Muriate, 80% bgs., unit	.53½–.....	.53½–.....	.53½–.....
Nitrate, bbl. lb.	.05½– .06	.05½– .06	.05½– .06
Permanganate, drums, lb.	.18½– .19	.18½– .19	.18½– .19
Prussate, yellow, casks, lb.	.15 – .16	.15 – .16	.15 – .16
Sal ammoniac, white, casks, lb.	.05 – .05½	.05 – .05½	.05 – .05½
Salsoda, bbl., cwt.	1.00 – 1.05	1.00 – 1.05	1.00 – 1.05
Salt cake, bulk, ton	13.00 –15.00	13.00 –15.00	13.00 –15.00
Soda ash, light, 58%, bags, contract, cwt.	1.23 –.....	1.23 –.....	1.23 –.....
Dense, bags, cwt.	1.25 –.....	1.25 –.....	1.25 –.....
Soda, caustic, 76%, solid, drums, contract, cwt.	2.60 – 3.00	2.60 – 3.00	2.60 – 3.00
Acetate, works, bbl., lb.	.04 – .05	.04 – .05	.04½– .05
Bicarbonate, bbl., cwt.	1.75 – 2.00	1.75 – 2.00	1.75 – 2.00
Bichromate, casks, lb.	.06½– .07	.06½– .07	.06½– .07
Bisulphate, bulk, ton	15.00 –16.00	15.00 –16.00	15.00 –16.00
Bisulphite, bbl., lb.	.03½– .04	.03½– .04	.03½– .04
Chlorate, kegs, lb.	.06½– .06½	.06½– .06½	.06½– .06½
Chloride, tech., ton	12.00 –14.75	12.00 –14.75	12.00 –14.75
Cyanide, cases, dom., lb.	.14 – .15	.14 – .15	.16½– .17
Fluoride, bbl., lb.	.07½– .08	.07½– .08	.07½– .08
Hyposulphite, bbl., cwt.	2.40 – 2.50	2.40 – 2.50	2.40 – 2.50
Metasilicate, bbl., cwt.	2.20 – 3.20	2.20 – 3.20	2.15 – 3.15
Nitrate, bags, cwt.	1.45 –.....	1.45 –.....	1.45 –.....
Nitrite, casks, lb.	.06½– .07	.06½– .07	.07 – .08
Phosphate, dibasic, bags, lb.	1.85 –.....	1.85 –.....	1.70 – .024
Prussiate, yel. drums, lb.	.09½– .10	.09½– .10	.10 – .11
Silicate (40° dr.) wks., cwt.	.80 – .85	.80 – .85	.80 – .85
Sulphide, fused, 60–62%, dr., lb.	.02½– .03½	.02½– .03	.02½– .03
Sulphite, cyrs., bbl., lb.	.02½– .02½	.02½– .02½	.02½– .02½
Sulphur, crude at mine, bulk, ton	16 00 –.....	18.00 –.....	18.00– .....
Chloride, dr., lb.	.03 – .04	.03 – .04	.03½– .04
Dioxide, cyl., lb.	.07 – .08	.07 – .08	.07 – .07½
Flour, bag, cwt.	1.60 – 3.00	1.60 – 3.00	1.60 – 3.00
Tin Oxide, bbl., lb.	.50 –.....	.48 –.....	.52 –.....
Crystals, bbl., lb.	.36½–.....	.35 –.....	.34 –.....
Zinc. chloride, gran., bbl., lb.	.05 – .06	.05 – .06	.05 – .06
Carbonate, bbl., lb.	.14 – .15	.14 – .15	.09 – .11
Cyanide, dr., lb.	.33 – .35	.33 – .35	.36 – .38
Dust, bbl., lb.	.07 –.....	.07 –.....	.077–.....
Zinc oxide, lead free, bag., lb.	.06½–.....	.06½–.....	.06½–.....
5% lead sulphate, bags, lb.	.06½–.....	.06½–.....	.06½–.....
Sulphate, bbl., cwt.	3.15 – 3.60	3.15 – 3.60	3.15 – 3.60

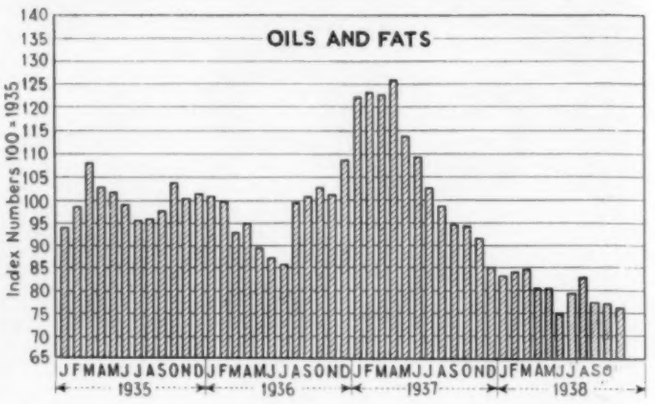
OILS AND FATS

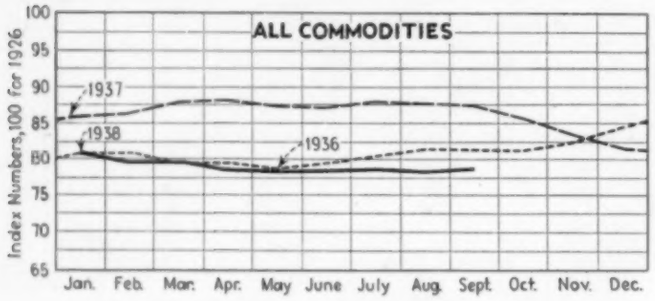
	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb.	$0.09½–$0.10	$0.09½–$0.10	$0.10½–$0.11
Chinawood oil, bbl., lb.	.14 –.....	.12½–.....	.17 –.....
Coconut oil, Ceylon, tanks, N. Y. lb.	.03 –.....	.03½–.....	.04½–.....
Corn oil crude, tanks (f.o.b. mill), lb.	.06½–.....	.07 –.....	.06½–.....
Cottonseed oil, crude (f.o.b. mill), tanks, lb.	.06½–.....	.06½–.....	.06 –.....
Linseed oil, raw car lots, bbl., lb.	.083–.....	.086–.....	.108–.....
Palm, casks, lb.	.036–.....	.036–.....	.04½–.....
Peanut oil, crude, tanks (mill), lb.	.06½–.....	.07 –.....	.07½–.....
Rapeseed oil, refined, bbl., gal.	.78 –.....	.75 –.....	.92 –.....
Soya bean, tank, lb.	.05½–.....	.05½–.....	.06 –.....
Sulphur (olive foots), bbl., lb.	.06½–.....	.06½–.....	.09½–.....
Cod, Newfoundland, bbl., gal.	.38 –.....	.38 –.....	.52 –.....
Menhaden, light pressed, bbl., lb.	.063–.....	.061–.....	.074–.....
Crude, tanks (f.o.b. factory), gal.	.30 –.....	.30 –.....	.35 –.....
Grease, yellow, loose, lb.	.04½–.....	.04½–.....	.05½–.....
Oleo stearine, lb.	.06½–.....	.07 –.....	.09 –.....
Oleo oil, No. 1	.09½–.....	.09½–.....	.10½–.....
Red oil, distilled, d.p. bbl., lb.	.08½–.....	.08½–.....	.10½–.....
Tallow extra, loose, lb.	.05½–.....	.05½–.....	.06½–.....

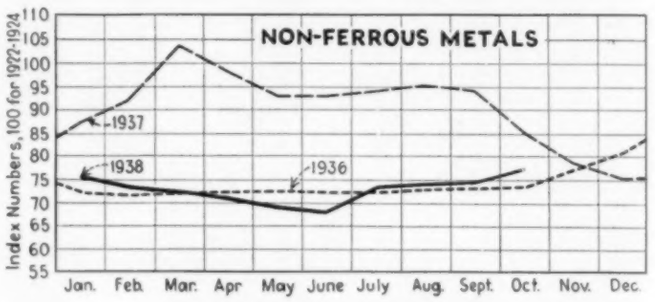
The accompanying prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to Nov. 14

Chem. & Met.'s Weighted Price Indexes









COAL-TAR PRODUCTS

	Current Price	Last Month	Last Year
Alpha-napthol, crude bbl., lb.	$0.52 -$0.55	$0.52 -$0.55	$0.52 -$0.55
Alpha-naphthylamine, bbl., lb.	.32 - .34	.32 - .34	.32 - .34
Aniline oil, drums, extra, lb.	.15 - .16	.15 - .16	.15 - 16
Aniline salts, bbl., lb.	.22 - .24	.22 - .24	22 - .24
Benzaldehyde, U.S.P., dr., lb.	.85 - .95	.85 - .95	.85 - .95
Benzidine base, bbl., lb.	.70 - .75	.70 - .75	.70 - .75
Benzoic acid, U.S.P., kgs., lb.	.54 - .56	.54 - .56	.52 - .54
Benzyl chloride, tech., dr., lb.	.23 - .25	.25 - .27	.25 - .27
Benzol, 90%, tanks, works, gal.	.16 - .18	.16 - .18	.16 - .18
Beta-napthol, tech., drums, lb.	.23 - .24	.23 - .24	.23 - .24
Cresol, U.S.P., dr., lb.	.10½- .11	10½ - .11	.12 - .13
Cresylic acid, dr., wks., gal.	.78 - .80	78 - .80	.92 - 1.00
Diethylaniline, dr., lb.	.40 - .45	.40 - .45	.50 - .55
Dinitrophenol, bbl., lb.	.23 - .25	.23 - .25	.23 - .25
Dinitrotoluen, bbl., lb.	.15 - .16	.15 - .16	.15 - .16
Dip oil, 15%, dr., gal.	.23 - .25	.23 - .25	.23 - .25
Diphenylamine, bbl., lb.	.32 - .36	.32 - .36	.32 - .36
H-acid, bbl., lb.	.50 - .55	.50 - .55	.50 - .55
Naphthalene, flake, bbl., lb.	.05½- .06	05½ - .06	.07½- .07½
Nitrobenzene, dr., lb.	.08 - .09	.08 - .09	.08 - .09
Para-nitraniline, bbl., lb.	.47 - .49	.50 .52	.45 - .47
Phenol, U.S.P., drums, lb.	.14½-.....	.14½-.....	.14½-.....
Picric acid, bbl., lb.	.35 - .40	.35 - .40	.35 - .40
Pyridine, dr., gal.	1.55 - 1.60	1.55 - 1.60	1.55 - 1.60
Resorcinal, tech., kegs, lb.	.75 - .80	.75 - .80	.75 - .80
Salicylic acid, tech., bbl., lb.	.33 - .40	.33 - .40	.34 - .40
Solvent naptha, w.w., tanks, gal.	.26 -.....	.26 -.....	.30 -.....
Tolidine, bbl., lb.	.86 - .88	.88 - .90	.88 - .90
Toluene, tanks, works, gal.	.27 -.....	.27 -.....	.35 -.....
Xylene, com, tanks, gal.	.26 -.....	.26 -.....	.35 -.....

MISCELLANEOUS

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton.	$22.00-$25.00	$22.00-$25.00	$22.00-$25.00
Casein, tech., bbl., lb.	.08- .11	.08½- .11	.17½- .18½
China clay, dom., f.o.b. mine, ton.	8.00 -20.00	8.00 -20.00	8.00 -20.00
Dry colors			
Carbon gas, black (wks.), lb.	.02½- .30	.02½- .30	.0395- .30
Prussian blue, bbl., lb.	.36 - .37	.36 - .37	.37 - .38
Ultramarine blue, bbl., lb.	.10 - .26	.10 - .26	.10 - .26
Chrome green, bbl., lb.	.21 - .30	.21 - .30	.21 - .27
Carmine red, tins, lb.	4.00 - 4.40	4.00 - 4.40	4.00 - 4.40
Para toner, lb.	.75 - .80	.75 - .80	.75 - .80
Vermilion, English, bbl., lb.	1.50 - 1.55	1.50 - 1.55	1.65 - 1.70
Chrome yellow, C. P., bbl., lb.	.14½- .15½	.14½- .15½	.14½- .15½
Feldspar, No. 1 (f.o.b. N.C.), ton.	6.50 - 7.50	6.50 - 7.50	6.50 - 7.50
Graphite, Ceylon, lump, bbl., lb.	.06 - .06½	.06 - .06½	.06 - .06½
Gum copal Congo, bags, lb.	.06 - .30	.06 - .30	.08 - .30
Manila, bags, lb.	.07 - .14	.07 - .14	.09 - .14
Damar, Batavia, cases, lb.	.16 - .24	.16 - .24	.15½- .16
Kauri cases, lb.	.17½- .60	.17½- .60	.19 - .25
Kieselguhr (f.o.b. N. Y.), ton.	50.00 -55.00	50.00 -55.00	50.00 -55.00
Magnesite, calc, ton.	50.00 -.....	50.00 -.....	50.00 -.....
Pumice stone, lump, bbl., lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks, lb.	.03 - .04	.03 - .04	.03 - .04
Rosin, H., bbl.	6.55 -.....	6.65 -.....	7.75 -.....
Turpentine, gal.	.29 -.....	.27 -.....	.31½-.....
Shellac, orange, fine, bags, lb.	.20 -.....	20 -.....	.22 - . .
Bleached, bonedry, bags, lb.	.19 -.....	.19 -.....	.17 -.....
T. N. Bags, lb.	.10½-.....	.11 -.....	.12 -.....
Soapstone (f.o.b. Vt.), bags, ton.	10.00 -12.00	10.00 -12.00	10.00 -12.00
Talc, 200 mesh (f.o.b. Vt.), ton.	8.00 - 8.50	8.00 - 8.50	8.00 - 8.50
300 mesh (f.o.b. Ga.), ton.	7.50 -10.00	7.50 -10.00	7.50 -11.00
225 mesh (f.o.b. N. Y.), ton.	13.75 -.....	13.75 -.....	13.75 -.....

INDUSTRIAL NOTES

LINDE AIR PRODUCTS CO., New York, has promoted T. D. Cartledge to the position of general sales manager. He succeeds J. N. Walker, who has been made vice-president of Oxweld Acetylene Co. Both these companies are units of Union Carbide and Carbon Corp.

PARAMET CHEMICAL CORP., Long Island City, has appointed C. Homer Flynn sales manager.

The SCOMET ENGINEERING CO., Carteret, N. J., has taken over the work formerly carried on by the oxygen-free copper department of the United States Metals Refining Co. The American Metal Co., Ltd., New York, will continue to handle the sale of the metal.

The CRANE PACKING CO., Chicago, announces the appointment of John Kirgan as New York manager.

The HYDRAULIC PRESS MFG. CO., Mount Gilead, Ohio, has elected Howard F. MacMillin president to succeed his father, F. B. MacMillin, who died on September 8.

GENERAL ALLOYS CO., Boston, has appointed Walter Gerlinger, Inc., 610 W. Michigan St., Milwaukee, as its representative for all of Wisconsin.

MICHIANA PRODUCTS CORP., Michigan City, Ind., has named George R. Gregg its representative in the Pittsburgh area with headquarters in the Clark Bldg.

SPROUT, WALDRON & CO., Muncy, Pa., is now represented in New Orleans by the Sintes Sales Engineers, 206 Masonic Temple Bldg.

The WEBSTER MFG. CO., Tiffin, Ohio, which has been operated under a trusteeship, has been reorganized and the company will be known as WEBSTER MANUFACTURING, INC., and will remain under the same management.

New CONSTRUCTION

PROPOSED WORK

Laboratory—Philip Ruxton, Inc., 75 Varick St., New York, N. Y., division of International Printing Ink Corp., is having plans prepared by E. L. Kear, Archt., 545 Fifth Ave., New York, N. Y., for the construction of a 7-story laboratory building at 428–30 West 45th St., New York, N. Y. Estimated cost $175,000.

Mill—Canadian Flint & Spar Co., Ltd., Peterborough, Ont., Can., is having plans prepared and will soon receive bids for the construction of new mill buildings. Estimated cost $200,000.

Mill—L. Dorsay, E. Schenee and J. A. Jacobs, 2226 Dorchester St., W., Montreal, Que., Can., are having plans prepared for the construction of a mill to utilize about 100,000 tons of waste wood pulp now in the Snye Channel of the Ottawa River, Hawkesbury, Ont. Estimated cost $50,000.

Oil Refinery—Allied Oil Co. of Illinois, St. Elmo, Ill., plans to rebuild its oil refinery, including laboratories, etc., recently destroyed by fire. Estimated cost will exceed $40,000.

Oil Refinery—Anglo Canadian Oil Co., Ltd., Calgary, Alta., Can., is having plans prepared for the construction of a refinery to have a capacity of 5,000,000 bbls. per day. J. P. Byrne, Calgary, Managing Director. Estimated cost $1,000,000.

Oil Refinery—Hydro Pete Oils, Ltd., Calgary, Alta., Can., plans to construct an oil refinery at Medicine Hat, Alta. Estimated cost $50,000.

Oil Refinery—Shell Petroleum Corp., C. B. Singleton, Purch. Agt., 1221 Locust St., St. Louis, Mo., will soon award the contract for the construction of a 2 story, 170x330 ft. compound house at its oil refinery at Roxana, Ill., to replace building destroyed by fire several months ago.

Oil Refinery—J. Wood Glass, Nowata, Okla., and S. C. Henderson and Associates, plan to construct an absorption and repressuring plant in the Agua Dulce fields, about 30 mi. west of Corpus Christi, Tex., to have a capacity of 75,000,000 cu. ft. gas daily which will process about 50,000 gal. of high Octane gasoline and considerable byproducts. Estimated cost $375,000.

Plant—Celanese Corporation of America, 180 Madison Ave., New York, N. Y., contemplates the construction of a plant near Pearisburg, Va. Estimated cost $10,000,000.

Textile Yarn Plant—E. I. duPont de Nemours & Co., Wilmington, Del., has acquired a 340-acre tract of land about one mile southwest of Seaford, Del., and plans to construct a textile yarn plant. Estimated cost $7,000,000.

Pulp Plant—Deep River Development Co., Ltd., Victoria, B. C., Can., plans the construction of a rayon pulp plant. Estimated cost $350,000.

Rubber Factory—Mansfield Tire & Rubber Co., Mansfield, O., contemplates the construction of a 2 story factory building. Estimated cost $100,000.

Rubber Factory—Wooster Rubber Co., Wooster, O., plans to construct a 2 story, 50x80 ft. addition to its factory. Bids will be called in about thirty days. Estimated cost $40,000.

Where Plants Are Being Built in Process Industries

	Current Projects		Cumulative 1938	
	Proposed Work	Contracts	Proposed Work	Contracts
New England	.....	.....	$340,000	$1,179,000
Middle Atlantic	$175,000	$1,125,000	8,979,000	9,913,000
South	10,700,000	.....	38,620,000	12,086,000
Middle West	180,000	243,000	14,102,000	5,812,000
West of Mississippi	665,000	165,000	19,797,000	5,255,000
Far West	115,000	150,000	1,335,000	3,122,000
Canada	1,700,000	175,000	23,244,000	4,935,000
Total	$13,535,000	$1,858,000	$106,417,000	$42,302,000

Salt Refinery—Crystal White Salt Co., c/o N. W. Clayton, Jr., Pres., 1077 First Ave., Salt Lake City, Utah, plans to construct a salt refining plant along the shore of Great Salt Lake about 5 mi. west of Grantsville, Utah. Estimated cost $75,000.

Seed-Meal Processing Plant — Great Lakes Feed Co., Ltd., Canadian Pacific Ry. Bldg., Toronto, Ont., Can., has had plans prepared for a seed-meal processing plant on St. Catherine St., Hamilton, Ont. Equipment will be installed. MacDonald Engineering Co., Ltd., 512 Canadian Pacific Ry. Bldg., Toronto, Engr. Estimated cost $50,000.

Sulphur Refining Plant—O. G. Avery, 51 Atlantic Ave., Long Beach, Calif., plans to construct a sulphur refining plant in the Fish Lake Valley District, Esmeraldo Co., Coaldale, Nev. Machinery and equipment will be purchased and installed. George A. Anderson, c/o owner, Engr. Estimated cost $40,000.

Tannery—Texas State Manufacturers Assn., c/o Albert T. Clifton, Pres., Waco, Tex., plans to construct a tannery at San Antonio, Tex. Estimated cost $250,000.

CONTRACTS AWARDED

Asphalt Plant—City of Cleveland, Jack Werrick, Asst. Ch. Engr., Cleveland, O., has awarded the contract for the construction of an asphalt plant to F. D. Cummer & Son Co., Keith Bldg., Cleveland. Estimated cost including labor and material, operating cost and fixed annual capital charge $242,-512.

Cement Plant—Lehigh Portland Cement Co., Hamilton St., Allentown, Pa., has awarded the contract for additions and improvements to its plant at Alsen, N. Y., to E. C. Machine Co., Commonwealth Bldg., Allentown. Estimated cost $250,000 plus.

Factory—Afga Ansco Corp., Charles St., Binghamton, N. Y., has awarded the contract for extensive alterations to Buildings 14 and 29, to W. E. Wark & Co., 1608 Walnut St., Philadelphia, Pa. Estimated cost $40,000.

Factory—Johnston Tin Foil & Metal Co., 6106 South Bway., St. Louis, Mo., has awarded the general contract for a 1-story, 100x100 ft. addition to its factory to Woermann Construction Co., 3800 West Pine Blvd., St. Louis. Estimated cost $40,000.

Factory—Pioneer Flintkote Co., 55 South Alameda St., Vernon, Calif., has awarded the contract for a 270x350 ft. factory and warehouse at 2051 East 55th St., Los Angeles, to Austin Co. of California, 777 East Washington Blvd., Los Angeles. Estimated cost will exceed $150,000.

Factory—Staso Milling Co., subsidiary of Central Commercial Co., manufacturer of minerals for surfacing shingles, Somerville, N. J., has awarded the contract for the design and construction of a plant comprising nine buildings, to the Austin Co., 19 Rector St., New York, N. Y. Estimated cost $750,000.

Laboratory—Ciba Pharmaceutical Products, Inc., Lafayette Park, Summit, N. J., has awarded the contract for the construction of a laboratory and animal house at Walter Kidde Constructors, Inc., 140 Cedar St., New York, N. Y. Estimated cost $50,000.

Oil Refinery—British American Oil Co., Ltd., Canadian Pacific Ry. Bldg., Toronto, Ont., Can., has awarded the contract for an addition to its refinery on Winnipeg St., Sask., to Poole Construction Co., Ltd., Eighth St., Regina. Estimated cost $75,000.

Plant—Chromium Mining & Smelting Corp., 6 James St., S., Hamilton, Ont., Can., is building an addition to its plant at Sault Ste Marie, Ont., and will install two 5500 k.w. furnaces, transformers and equipment. Estimated cost $60,000.

Plant—Westminster Paper Co., Ltd., New Westminster, B. C., Can., has awarded the contract for a 3 story, 90x108 ft. plant to Dominion Construction Co., Ltd., 509 Richards St., Vancouver, B. C. Estimated cost $40,000

Sulphur Plant—Southern Acid & Sulphur Co., Texarkana, Tex., has awarded the contract for constructing four buildings at its proposed plant on Wallisville Rd., near Houston, Tex., to Austin Co., Second National Bank Bldg., Houston. Estimated cost $125,000.

Electric Precipatator—Calco Chemical Co., Bound Brook, N. J., has awarded the contract for an electric precipitator to W. B. Conner Engineering Co., 114 East 32 St., New York, N. Y. Estimated cost $35,000.

MARKED GAIN IN PRODUCTION OF BYPRODUCT COKE PRODUCTS LAST YEAR

FINAL figures on the coke industry for 1937 have been issued by the U. S. Bureau of Mines. Total production of coke was 52,375,469 tons which compares with 46,275,184 tons produced in 1936. Of the 1937 output 49,210,748 tons, or nearly 94 per cent of the total, was produced at byproduct plants with beehive production continuing to become less important. The status of beehive activities is further shown by the fact that 749 ovens were dismantled during the year. Total value of coke, breeze, and byproducts was $411,706,484 compared with $368,652,221 for 1936, with the largest relative gain reported for ammonium sulphate or equivalent.

Production of sulphate of ammonia was placed at 1,289,740,739 lb. as against 1,199,645,603 lb. for 1936. Ammonia liquor, expressed in terms of NH_3 content, was reported at 54,172,628 lb. for 1937 and 47,259,245 lb. for 1936. Hence the increase over 1936 for ammonium sulphate or equivalent is found to rest more on enlarged output of liquor rather than on that of ammonium sulphate.

Tar production reached a total of 603,053,288 gal. in 1937, which was appreciably higher than the 560,385,578 gal. produced in 1936. Sales of tar amounted to 386,648,478 gal. and 358,182,759 gal. for 1937 and 1936 respectively. The average value for sales in 1937 was 4.8¢ a gal. and in 1936, 4.3¢ a gal.

Statistics for crude light oil production show a total original supply of 187,054,346 gal. of which 11,113,150 gal. was sold as such. In 1936, production was 170,234,202 gal. with sales of 10,363,176 gal.

Light oil derivatives reflected the larger supply of available crude oil and were turned out to the extent of 156,502,306 gal., which topped by a good margin the 140,972,234 gal. produced in 1936. Sales of derivates were 151,105,055 gal. in 1937 and 136,294,329 gal. in the preceding year.

In view of reports of a scarcity of motor benzol in recent months, it is of interest to note that production last year advanced to 95,526,695 gal. from the 85,672,953 gal. reported for 1936. Sales in 1937 were 93,767,208 gal., which would not leave much of a carryover to compensate for the smaller production in the current year. Sales in 1936 also were close to production, amounting to 84,761,655 gal. For benzol (except motor benzol) production totals for 1937 and 1936 were 26,795,497 gal. and 19,412,593 gal. respectively.

The figures for production and sales of crude and refined naphthalene for 1937 are of particular interest because of the sharp gains reported. Production was given at 115,979,238 lb. and sales at 109,394,319 lb. while the comparable totals for 1936 were 37,552,219 lb. and 34,946,890 lb.

Production of Coke, Breeze, Gas, and Byproducts at Byproduct Coke Plants Owned by City Gas Companies and at All Other Byproduct Coke Plants, 1937

Product		Plants not owned by city gas companies	Plants owned by city gas companies	Total
Number of active plants		65	20	85
Coke: Production	net tons	45,699,231	3,511,517	49,210,748
Value		$223,873,967	$23,481,785	$247,355,752
Average value		$4.90	$6.69	$5.03
Screening or breeze: Production	net tons	3,577,183	306,515	3,883,698
Sales	net tons	633,108	24,037	657,145
Value		$1,473,253	$61,884	$1,535,137
Average value		$2.33	$2.57	$2.34
Coal charged into ovens	net tons	64,594,504	4,980,869	69,575,373
Coke: Used by producer:				
Quantity	net tons	31,500,121	729,776	32,229,897
Value		$139,929,373	$4,368,964	$144,298,337
Sales: Quantity	net tons	13,407,427	2,742,688	16,150,115
Value		$79,857,905	$18,840,495	$98,698,400
Byproducts:				
Gas:				
Production	M cu. ft.	699,623,138	58,005,804	757,628,942
Sales of surplus:				
Used under boilers:	M cu. ft.	32,750,748	26,010	32,776,758
Value		$1,968,036	$1,657	$1,969,693
Used in steel or affiliated plants:	M cu. ft.	251,552,978	18,671	251,571,649
Value		$25,413,963	$5,260	$25,419,223
Distributed through city mains:	M cu. ft.	99,374,929	51,561,739	150,936,668
Value		$24,734,750	$17,923,075	$42,657,825
Sold for industrial use:	M cu. ft.	26,290,137	1,467,747	27,757,884
Value		$2,515,049	$399,907	$2,914,956
Tar: Production	gal.	555,607,964	47,445,324	603,053,288
Sales:	gal.	341,254,792	45,393,686	386,648,478
Value		$16,397,396	$2,059,087	$18,456,483
Average value		$0.048	$0.045	$0.048
Ammonia: Production (NH_3 equivalent of all forms)	lb.	350,803,763	25,804,050	376,607,813
Liquor (NH_3 content)	lb.	49,717,008	4,455,620	54,172,628
Sales	lb.	47,970,372	4,424,345	52,394,717
Value		$1,482,593	$88,498	$1,571,091
Sulphate:	lb.	1,204,347,020	85,393,719	1,289,740,739
Sales	lb.	1,246,437,212	85,871,536	1,332,308,748
Value		$13,533,822	$943,412	$14,477,234
Crude light oil: Production	gal.	183,223,825	3,830,521	187,054,346
Sales	gal.	8,322,515	2,790,635	11,113,150
Value		$707,807	$247,652	$955,459
Light oil derivatives: Production	gal.	155,610,298	892,008	156,502,306
Sales	gal.	150,225,547	879,508	151,105,055
Value		$19,128,211	$131,734	$19,259,945
Naphthalene, crude and refined: Production	lb.	59,863,754	933,354	60,797,108
Sales	lb.	59,384,227	931,354	60,315,581
Value		$1,167,536	$15,456	$1,182,992
All other products, value		$3,126,280	$133,657	$3,259,937

Production and Sales of Coal-Tar Crudes at Byproduct Coke Plants and Tar Refineries, 1937

	Unit of quantity	Production quantity	Sales		Unit value
			Quantity	Value	
Tar	gal.	603,053,288	386,648,478	$18,456,483	$0.048
Light oil derivatives:					
Crude light oil	gal.	187,103,087	11,153,337	962,836	.086
Benzol (except motor benzol)	gal.	26,795,497	22,140,936	2,928,471	.132
Motor benzol	gal.	95,526,695	93,767,208	8,384,863	.089
Toluol, crude and refined	gal.	20,896,724	20,173,723	5,350,087	.265
Solvent naphtha	gal.	7,077,114	6,343,220	1,295,500	.204
Xylol	gal.	4,562,344	4,245,316	1,176,723	.277
Other light oil products	gal.	12,842,115	11,806,798	1,871,115	.158
Naphthalene, crude and refined	lb.	115,979,238	109,394,319	2,534,526	.023
Creosote oil	gal.	107,293,751	107,485,199	12,472,500	.116
Tars, crude and refined	gal.	23,756,212	23,144,241	1,711,437	.074
Tars, road	gal.	155,088,720	155,745,590	12,907,947	.083
Other distillates	gal.	34,550,805	8,313,627	1,406,736	.169
Pitch of tar	ton	893,715	315,443	4,382,466	13.893
Pitch of tar coke	ton	181,495	91,983	1,131,812	12.305

Chem & Met.

DATA SHEETS

A guide to the chemical engineer in the selection of materials that will be resistant to corrosion, heat and abrasion.

CHEMICAL & METALLURGICAL ENGINEERING

McGRAW-HILL PUBLISHING COMPANY, INC.

Chem & Met.

DATA SHEETS ON MATERIALS OF CONSTRUCTION

1938-1939 EDITION

CHEMICAL ENGINEERS interested in selection of suitable materials for construction of equipment used in the process industries will find helpful up-to-date reference data in the following pages. Essential information is presented for more than 800 corrosion-, heat- and abrasion-resistant materials. There are three general classifications: (a) Non-Ferrous Metals and Alloys; (b) Ferrous Metals and Alloys; and (c) Non-Metallic Materials of Construction. These types or any of the 25 major subdivisions may be quickly located by referring to the following "Table of Contents." Attention is called to the fact, however, that since the 1936-1937 Edition there have been many changes in chemical composition, trade names and manufacturing companies. Therefore, where it is desirable to locate immediately some particular materials for which the generic or trade name is known, it is recommended that the reader turn immediately to the detailed "Index of Materials" on pages 663-664.

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MAKERS OF COPPER AND COPPER BASE ALLOYS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Ad Aluminum	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 82; Zn, 15; Al, 2; Sn, 1	T
2	Admiralty	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 70; Zn, 29; Sn, 1	S, T, W
3	Admiralty	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 70; Zn, 29; Sn, 1	D, T, extruded
4	Admiralty	Scovill Mfg. Co., Waterbury, Conn.	Cu, 70; Zn, 29; Sn, 1	CR, D, S, R, T, W
5	Adnic	Scovill Mfg. Co., Waterbury, Conn.	Cu, 70; Ni, 29; Sn, 1	CR, D, S, R, T, W
6	Advance	Driver-Harris Co., Harrison, N. J.	Cu, 55; Ni 45	HR, CR, D, P, S, W, B
7	Alcumite	Duriron Co., Dayton, Ohio	Cu, 89.75; Al, 9; Fe, 1.25	B, C, HR
8	Alcunic	Scovill Mfg. Co., Waterbury, Conn.	Cu, 80; Zn, 16; Sn, 1; Ni, 1	CR, D, R, T, W, strip
9	Aluminum Brass	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 76; Zn, 22; Al, 2	T
10	Aluminum Brass	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 76; Zn, 22; Al, 2	D, R, T, extruded
11	Aluminum Brass	Scovill Mfg. Co., Waterbury, Conn.	Cu, 76; Zn, 22; Al, 2	CR, D, T
12	Aluminum Bronze	American Brass Co., Waterbury Conn.	Cu, 88-96; Al, 4-10.5; Fe; Ni; Sn	B, C, CR, HR, D, P, S, R, T, W
13	Ambrac 850	American Brass Co., Waterbury, Conn.	Cu, 75; Ni, 20; Zn, 5	B, C, CR, HR, D, P, S, R, T, W
14	Ambraloy 927	American Brass Co., Waterbury, Conn.	Cu, 76; Zn, 22; Al, 2	CR, D, P, S, T
15	Ampco 16	Ampco Metal Inc., Milwaukee, Wis.	Cu, 86.1; Al, 10.2; Fe, 3.3	B, C, HR, S, R, W
16	Ampco 18	Ampco Metal Inc., Milwaukee, Wis.	Cu, 84.6; Al, 11.3; Fe, 3.7	C
17	Ampco 20	Ampco Metal Inc., Milwaukee, Wis.	Cu, 83.1; Al, 12.4; Fe, 4.1	C
18	Ampco 21	Ampco Metal Inc., Milwaukee, Wis.	Cu, 83.3; Al, 13.1; Fe, 4.1	C
19	Ampcoloy 40	Ampco Metal Inc., Milwaukee, Wis.	Cu, 90; Al, 10	C
20	Ampcoloy 50	Ampco Metal Inc., Milwaukee, Wis.	Cu, 84; Sn, 10; Ni, 3.5; Pb, 2.5	C
21	Ampcoloy A-3	Ampco Metal Inc., Milwaukee, Wis.	Cu, 89; Al, 10; Fe, 1	C
22	Ampcoloy E-1	Ampco Metal Inc., Milwaukee, Wis.	Cu, 89; Al, 10; Fe, 1	C
23	Ampcoloy E-133	Ampco Metal Inc., Milwaukee, Wis.	Cu, 89; Al, 10; Fe, 1	C
24	Arsenical Copper	Scovill Mfg. Co., Waterbury, Conn.	Cu; As, 0.15-0.75	D, T.
25	Beryllium Copper	American Brass Co., Waterbury, Conn.	Cu; 97.4; Be, 2.25; Ni, 0.35	B, C, CR, HR, D, P, S, R, W
26	Beryllium Copper	Beryllium Corp. of Pa., Reading, Pa.	Cu; 98; Be, 2	B, C, CR, HR, D, P, S, R, T, W
27	600 Bearing Metal	Mueller Brass Co., Port Huron, Mich.		R, forgings
28	Cataract Metal	Niagara Falls Smelting & Ref. Corp., Buffalo, N. Y.	Cu; Ni	Ingots
29	Chromium Copper	American Brass Co., Waterbury, Conn.	Cu, 99.05; Cr, 0.85; Si, 0.10	B, C, CR, HR, D, P, S, R, W
30	Commercial Bronze	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 90; Zn, 10	CR, HR, D, R, W, strip
31	Cramp 49	Cramp Brass & Iron Fdries. Co., Philadelphia, Pa.	Cu, 63-68; Zn, 21-24; Mn, 2-5; Fe, 2-4	B, C, HR, forged
32	Cramp 99	Cramp Brass & Iron Fdries. Co., Philadelphia, Pa.	Cu, 94-96; Si, 3-4; Fe, 1-2	B, C, CR, HR, forged
33	Cupaloy	Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.	Cu, 99.4; Cr, 0.5; Ag, 0.1	B, C, CR, HR, D, R
34	Cupron	Wilber B. Driver Co., Newark, N. J.	Cu, 55; Ni, 45	W, ribbon
35	Cupro-Nickel 20%	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 80; Ni, 20	P, T
36	Cupro-Nickel 30%	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 70; Ni, 30	P, T
37	Cupro-Nickel	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 70-80; Ni, 20-30	B, R, T, strip, extruded
38	Cupro-Nickel 70-30	Revere Copper & Brass, Inc., New York, N. Y.	Cu, 70; Ni, 30	P, T
39	Cupro-Nickel 80-20	Scovill Mfg. Co., Waterbury, Conn.	Cu, 80; Ni, 20	CR, D, S, R, T, W
40	Cupro-Nickel 70-30	Scovill Mfg. Co., Waterbury, Conn.	Cu, 70; Ni, 30	CR, D, S, R, T, W
41	Deoxidized Copper	American Brass Co., Waterbury, Conn.	Cu, 99.90 +; P, 0.02	B, C, CR, HR, D, P, S, R, T, W
42	Duronze 1	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 97; Sn, 2; Si, 1	B, CR, HR, S, R, W
43	Duronze 2	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 97; Si, 3	B, CR, HR, D, P, S, R, W
44	Duronze 3	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 91; Al, 7; Si, 2	B, R
45	Elkonite W53	P. R. Mallory & Co., Indianapolis, Ind.	Cu alloy 30; W 70	B, P, R, T
46	Everbrite	Amer. Manganese Bronze Co., Philadelphia, Pa.	Cu, 60; Ni, 30; Fe, 3; Si, 3; Cr, 3	C
47	Everdur 1000	American Brass Co., Waterbury, Conn.	Cu, 94.9; Si, 4; Mn, 1.1	C
48	Everdur 1010	American Brass Co., Waterbury, Conn.	Cu, 95.8; Si, 3.1; Mn, 1.1	B, CR, HR, D, P, S, R, T, W
49	Everdur 1015	American Brass Co., Waterbury, Conn.	Cu, 98.25; Si, 1.5; Mn, 0.25	B, CR, HR, D, P, S, R, T, W
50	Free Cut Brass	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 60; Zn, 37; Pb, 3	D, R, W, extruded
51	Free Cutting Comm. Bronze	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 89; Zn, 9; Pb, 2	B, D, R
52	Free Cutting Phos. Bronze 610	American Brass Co., Waterbury, Conn.	Cu, 88; Sn, 4; Zn, 4; Pb, 4	B, CR, D, P, S, R
53	Frontier 5	Frontier Bronze Corp., Niagara Falls, N. Y.	Cu, 89; Al, 10; Fe, 1	C
54	Hardware Bronze	Scovill Mfg. Co., Waterbury, Conn.	Cu, 89; Zn 8; Pb, 2; Ni, 1	D, R, W
55	Herculoy A	Revere Copper & Brass, Inc., New York, N. Y.	Cu, 96.25; Si, 3.25; Sn, 0.5	B, C, CR, HR, D, P, S, R
56	Herculoy B	Revere Copper & Brass, Inc., New York, N. Y.	Cu, 97.75; Si, 2; Sn, 0.25	B, CR, HR, D, P, S, R, T
57	High Brass	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 66; Zn, 34	CR, D, S, W
58	High Brass	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 66; Zn, 34	B, CR, HR, D, R, T, W
59	Hills-McCanna 45	Hills McCanna Co., Chicago, Ill.	Cu, 89; Al, 10; Fe, 1	C
60	Hills-McCanna 52	Hills McCanna Co., Chicago, Ill.	Cu, 74.5; Ni, 16.5; Al, 9	C
61	Hytensl Bronze	Amer. Manganese Bronze Co., Philadelphia, Pa.	Cu, 63; Zn, 23; Al, 4; Fe, 3; Mn, 3	C, HR, S
62	Naval Brass	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 60; Zn, 39; Sn, 1	B, CR, HR, D, R, T, W
63	Naval Brass	Scovill Mfg. Co., Waterbury, Conn.	Cu, 60; Zn, 39.25; Sn, 0.75	D, R T, W
64	Ni AG (nickel silver)	Mueller Brass Co., Port Huron, Mich.	Cu, 46; Ni, 8-10; Mo, 0.25; Zn, remainder	R, forgings
65	Nickel Aluminum Bronze	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 91; Ni, 7.5; Al, 1.5	R
66	Nickel Silver 18%	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 65; Ni, 18; Zn, 17	CR, S, W
67	Nickel Silver 18% 719	American Brass Co., Waterbury, Conn.	Cu, 65; Ni, 18; Zn, 17	B, C, CR, D, P, S, R, T, W
68	Nickel Silver 18% 724	American Brass Co., Waterbury, Conn.	Cu, 55; Ni, 18; Zn, 27	B, C, CR, D, P, S, R, W
69	Nickel Silver 18% A	Scovill Mfg. Co., Waterbury, Conn.	Cu, 65; Ni, 18; Zn, 17	CR, D, S, R, W
70	Nickel Silver 18% A	Seymour Mfg. Co., Seymour, Conn.	Cu, 64; Ni, 18; Zn, 18	B, CR, D, P, S, R, W
71	Nickel Silver 18% B	Scovill Mfg. Co., Waterbury, Conn.	Cu, 55; Ni, 18; Zn, 27	CR, D, S, R, W
72	Oldsmoloy	Olds Alloys Co., Pasadena, Calif.	Cu, 44; Zn, 39; Ni, 14; Sn, 1.5	C
73	Olympic Bronze	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 96; Si, 3; Zn, 1	B, C, CR, HR, D, P, S, R, T, W
74	Omega Nickel Silver 18% A	Riverside Metal Co., Riverside, N. J.	Cu, 65; Ni, 18; Zn, 17	B, CR, D, P, S, R, W
75	Omega Nickel Silver 18% B	Riverside Metal Co., Riverside, N. J.	Cu, 55; Zn, 27; Ni, 18	B, CR, D, P, S, R, W

*Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
76	Omega Phosphor Bronze 30	Riverside Metal Co., Riverside, N. J.	Cu, 95.5; Sn, 4.3; P, 0.2	B, CR, D, P, S, R, W
77	Omega Phosphor Bronze 47	Riverside Metal Co., Riverside, N. J.	Cu, 91.6; Sn, 8.25; P, 0.15	B, CR, D, P, S, R, W
78	Omega Phosphor Bronze 209	Riverside Metal Co., Riverside, N. J.	Cu, 90; Sn, 10; P	B, CR, D, P, S, R, W
79	Oxygen Free Copper	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 99.99+	B, CR, D, R, T, W
80	P M G (cast)	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 94–96; Si, 3–4; Fe, 1–2	C
81	P M G (Wrought)	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 94–98; Si, 1.5–3.5; Fe, 0.5–1.6	B, C, CR, HR, D, P, S, R, T, W
82	Phosphor Bronze 351	American Brass Co., Waterbury, Conn.	Cu, 95; Sn, 5; P	B, CR, D, P, S, R, T, W
83	Phosphor Bronze 353	American Brass Co., Waterbury, Conn.	Cu, 92; Sn, 8; P	B, CR, D, P, S, R, T, W
84	Phosphor Bronze 354	American Brass Co., Waterbury, Conn.	Cu, 89.5; Sn, 10.5; P	B, CR, D, P, S, R, T, W
85	Phosphor Bronze A	Scovill Mfg. Co., Waterbury, Conn.	Cu, 95; Sn, 5	CR, D, S, R, W
86	Phosphor Bronze A	Seymour Mfg. Co., Seymour, Conn.	Cu, 95; Sn, 5	B, CR, D, R, W
87	Phosphor Bronze C	Scovill Mfg. Co., Waterbury, Conn.	Cu, 92; Sn, 8	CR, D, S, R, W
88	Phosphorized Copper	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 99.9+; P, 0.02	CR, HR, D, P, S, T
89	Red Brass 85	American Brass Co., Waterbury, Conn.	Cu, 85; Zn, 15	B, CR, D, P, S, R, T, W
90	Red Brass	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 85; Zn, 15	S, T, W
91	Red Brass	Phelps Dodge Copper Products Corp., New York, N. Y.	Cu, 85; Zn, 15	B, C, CR, HR, D, R, T, W
92	Red Brass	Scovill Mfg. Co., Waterbury, Conn.	Cu, 85; Zn, 15	CR, D, S, R, T, W
93	Resistac	Amer. Manganese Bronze Co., Philadelphia, Pa.	Cu, 88; Al, 10; Fe, 2	C, HR, P, S
94	Revalon	Revere Copper & Brass, Inc., New York, N. Y.	Cu, 76; Zn, 22; Al, 2	T
95	Roman Bronze	Revere Copper & Brass, Inc., New York, N. Y.	Cu, 60; Zn, 39.25; Sn, 0.75	P, R, W
96	Sumet Bronze	Buffalo Fdry. & Mach. Co., Buffalo, N. Y.	Cu, 70; Pb, 26; Sn, 4	B, C, R
97	Super Nickel	American Brass Co., Waterbury, Conn.	Cu, 70; Ni, 30	B, C, CR, HR, D, P, S, R, T, W
98	Tuf-Stuf	Mueller Brass Co., Port Huron, Mich.	Cu, 86.9; Al, 10; Fe, 3; Mn, 0.1	R, forgings
99	Wolverine Admiralty	Wolverine Tube Co., Detroit, Mich.	Cu, 70; Zn, 29; Sn, 1	B, T
100	Wolverine Arsenical Copper	Wolverine Tube Co., Detroit, Mich.	Cu & Ag., 99.2 min., As, 0.15–0.75; P, 0.015–0.035	B, T
101	Wolverine Brass 70-30	Wolverine Tube Co., Detroit, Mich.	Cu, 70; Zn, 30	B, T
102	Wolverine Comm. Bronze	Wolverine Tube Co., Detroit, Mich.	Cu, 90; Zn, 10	B, T
103	Wolverine Copper, Oxygen Free	Wolverine Tube Co., Detroit, Mich.	Cu & Ag, 99.9 min.; P, 0.015–0.035 optional	B, T
104	Wolverine High Brass	Wolverine Tube Co., Detroit, Mich.	Cu, 66; Pb, 0.80 max.; Zn, balance	B, T
105	Wolverine Red Brass	Wolverine Tube Co., Detroit, Mich.	Cu, 85; Zn, 15	B, T

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF COPPER BASE ALLOYS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32–212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Ad Aluminum	8.44	1810	0.97	0.23	Annealed tube	53		65				Fair	Good	DD, F, R, W, B
2	Admiralty	8.55	1718	1.12	0.27	Annealed tube	50	23	60		15		Fair	Fair	DD, F, R, B
3	Admiralty	8.53	1720	1.10	0.26	Tube	50–95		5–65	25–70	17	45–180	Fair	Fair	DD, F, R, W, B
4	Admiralty	8.52	1730	1.05	0.26	Annealed tube	50		70				Fair	Good	DD, F, R, W, B
5	Adnic	8.88	2201	0.91	0.07	Annealed strip	55	25	50		21		Fair	Good	DD, F, R, W, B
6	Advance	8.9	2210	0.82	0.05	Wrought	60–100	25–75	30–35	50–65			Good	No	DD, F, R, W, B
7	Alcumite	7.75	1900	0.93		Cast	65–70	23–25	30–35	30–35	16.5	120–140	Good	Fair	W, B
8	Alcunic	8.44	1800	1.0	0.23	Annealed tube	45	15	55		15		Fair	Fair	DD, F, R, B
9	Aluminum Brass	8.32	1780	0.97	0.24	Annealed tube	52		70				Fair	Good	DD, F, R, W, B
10	Aluminum Brass	8.33	1775	0.97	0.24	Rod	50–100	15–75	10–65	30–60	16	50–185	Fair	Fair	DD, F, R, W, B
11	Aluminum Brass	8.33	1780	1.02	0.23	Annealed tube	52	15	50		15		Fair	Fair	DD, F, R, B
12	Aluminum Bronze	7.9	1904–1940			Rod, soft to hard	52–125	25–70	4–70			60–190	Good		DD, F, R, B
13	Ambrac 850	8.86	2102	0.85	0.092	Soft to hard	50–115	17–67	2–50		19	58–160	Fair		DD, F, R, W, B
14	Ambralay 927	8.34	1778		0.225	Tube	90		10		15		Fair		DD, W, B
15	Ampco 16	7.63	1900–2000	0.815	0.116	Cast	70–80	32–37	18–22	16–20	15.4	131–156	Good	Good	R, W, B
16	Ampco 18	7.59	1900–2000	1.24	0.118	Cast	75–85	33–42	10–14		14.4	159–183	Free		R, W, B
17	Ampco 20	7.44	1900–2000	1.08	0.24	Cast	80–90	35–43	4–6		12	12–248	Fair	Good	W, B
18	Ampco 21	7.51	1900–2000	1.13	0.152	Cast	80–95	36–44	3–5		13.2	285–311	Fair	Good	W, B
19	Ampcoloy 40					Cast	65–70	24–28	25–30	25–30		110–120	Good	Fair	W, B
20	Ampcoloy 50		1800–3000			Cast	40–50	7–15	7–15	7–15		80–93	Good	Fair	W, B
21	Ampcoloy A-3		1800–2200	0.91		Cast	70–75	25–32	30–40	30–40	18.3	115–126	Good	Fair	W, B, forging
22	Ampcoloy E-1		1800–2000			Cast	70–80	40–45	12–20	14–20	17.5	131–143	Good	Fair	W, B
23	Ampcoloy E-133		1800–2000			Cast	80–100	45–55	12–15	13–17		163–179	Fair	Fair	W, B
24	Arsenical Copper	8.91	1981	0.98		Annealed tube	35	12	40		15		Fair	Poor	F, R, W, B
25	Beryllium Copper	8.23	1751			Soft	70	30	45		18	110	Fair	Good	DD, F
						Heat treated	175	130	6		19	340			
26	Beryllium Copper	8.23	1587–1751	0.91	0.25	Heat treated	175	134	6.3		18.9	345	Fair	Good	DD, F, R, W, B
27	600 Bearing Metal	8.07	1625			Drawn rod	90	65	10	20		170–228	Fair	Good	
28	Cataract Metal	8.8	2250–2350	0.95		Cast	45–50		20–25	25–30		90–100	Good	Good	Casting
29	Chromium Copper	8.9	1980		0.75	Heat treated wire	92	50	3				Fair		DD, F
30	Commercial Bronze	8.81	1868–1930	1.01	0.45	Rod	40–110	20–75	4–45	25–60	15	45–130	Fair	Fair	DD, F, R, W, B
31	Cramp 49	7.74	2000			Cast, rolled, forged	120	70	10	10	15	240	Good	Good	
32	Cramp 99	8.44	1900			Cast	50	25	20	20		100	Good	Good	
33	Cupaloy	8.93	1981	0.92	0.785	Heat treated	65–75	60–65	20–25	60	16	140–150	Good	Good	
34	Cupron	8.9		0.80		Wire	62								

* Methods of fabrication: DD, deep drawing; F, flanging; W, welding; R, riveting; B, brazing.

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. (Multiply by 10⁻⁶)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10⁶)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
35	Cupro-Nickel 20%	8.85	2100	0.91	0.09	Annealed sheet	55		35				Fair	Good	DD, F, R, W, B
36	Cupro-Nickel 30%	8.94	2230	0.90	0.07	Annealed sheet	60		33				Fair	Good	DD, F, R, W, B
37	Cupro-Nickel	8.94	2192–2237	0.90		Soft tube	50–60	20–25	30–45			60–170	Fair	Fair	DD, F, R, W, B
38	Cupro-Nickel 70-30	8.95	2200–2350		0.069	Tube, soft to hard	49–85	68–80	4–50		19	60–170	Fair	Fair	DD, F, R, W, B
39	Cupro-Nickel 80-20	8.94	2192	0.91	0.09	Annealed tube	50	20	50		21		Fair	Good	DD, F, R, W, B
40	Cupro-Nickel 70-30	8.94	2237	0.90	0.07	Annealed tube	55	20	50		26		Fair	Good	DD, F, R, W, B
41	Deoxidized Copper	8.93	1981	0.93	0.80	Rod	35–55	12–44	5–35	60–70	16	42–107	Tough		DD, F, R, W, B
42	Duronze 1	8.78	1900	0.93			90	50	8	60	15		Fair	Fair	DD, F, B
43	Duronze 2	8.54	1875	0.93		Annealed sheet	50	18	40		15		Fair	Fair	DD, F, W
44	Duronze 3	7.69	1815	0.92		Drawn rod	95	50	10	30	14		Good	Good	
45	Elkonite W 53					Heat treated	120	90	0.75			300	Good	Good	Sintering
46	Everbrite	8.8			0.06	Cast	75	45	14			170	Good	Good	
47	Everdur 1000	8.15	1830	0.94	0.066	Cast	50	20	20	25	15	80	Fair		W, B
48	Everdur 1010	8.54	1866	0.94	0.078	Soft to hard	50–145	20–75	5–65	40–80	15	60–200	Fair		DD, F, R, W, B
49	Everdur 1015	8.74	1931	0.94	0.129	Soft to hard	40–70	10–50	6–60		15		Fair		DD, F, R, W, B
50	Free Cut Brass	8.52	1700		0.21	Rod	45–65	25–55	15–35		13–15	65–160	Good	Fair	R, W, B
51	Free Cutting Comm. Bronze	8.84	1900	0.98	0.43		45		30		17		Good	Good	
52	Free Cutting Phos. Bronze 610	8.86	1830	1.00	0.133	Rod	60	45	20		15	120	Good		B
53	Frontier 5	7.5	1800	0.94		As cast	60–80	22–28	15–30				Good		
54	Hardware Bronze	8.85	1913	1.02	0.43	Annealed rod	38	16	35				Good	Poor	R, B
55	Herculoy A	8.54	1850–2050		0.086	Rod, soft to hard	60–125	25–100	5–65	40–75	15	80–250	Fair	Fair	DD, F, R, W, B
56	Herculoy B	8.70	1885–2085		0.117	Rod, soft to hard	50–100	17–85	5–55	65–80	15	53–240	Fair	Fair	DD, F, R, W, B
57	High Brass	8.46	1710	1.05	0.29	Sheet	46–92		3–64				Fair	Good	DD, F, R, W, B
58	High Brass	8.47	1710	1.05	0.29	Rod	45–100		5–60	45–75	13–14	50–160	Fair	Fair	DD, F, R, W, B
59	Hills-McCanna 45	7.5	1950–2000	0.95		Cast	70	31	16	22	14	130	Good	Good	
60	Hills-McCanna 52	7.8	2000–2100	0.83		Cast	92	57	2.5	4	19	220	Good	Good	
61	Hytensl Bronze	7.0		0.90		Cast	110	65	15	15	14.5	220	Good	Good	
62	Naval Brass	8.43	1625	1.19	0.28	Rod	50–120	35–75	5–55	40–50	14–15	90–180	Fair	Fair	R, W, B
63	Naval Brass	8.39	1625	1.19	0.28	Annealed wire	55	23	40	60			Fair	Good	R, W, B
64	Ni AG (nickel silver)					Rods & forgings	60–90	40–60	10–25			125–190	Good	Fair	
65	Nickel Aluminum Bronze	8.72	2055	0.89	0.16	Age hardened rod	100		15				Fair	Good	R, W, B
66	Nickel Silver 18%	8.74	2030		0.08	Sheet	60–87		3–40				Fair	Good	DD, F, R, W, B
67	Nickel Silver 18% 719	8.75	2030	0.94	0.080	Sheet	65–90		3–40		18	77–158	Fair		DD, F, R, W, B
68	Nickel Silver 18% 724	8.68	1931		0.073	Soft — hard	60–143		1–40		18		Fair		DD, F, R, W, B
69	Nickel Silver 18% A	8.75	2030		0.08	Annealed strip	50	21	45		18		Fair	Good	DD, F, R, W, B
70	Nickel Silver 18% A	8.75		1.00	0.08	Soft sheet	58	25	40			70	Good	Good	DD, F, R, W, B
71	Nickel Silver 18% B	8.69	1931		0.07	Annealed strip	50	21	40		16		Fair	Good	DD, F, R, W, B
72	Oldsmoloy		2200				75	57–60	15–20	21.7	15.3	153	Good	Good	
73	Olympic Bronze	8.58	1880	0.94	0.08	Sheet	56–110		5–65				Fair	Good	DD, F, R, W, B
74	Omega Nickel Silver 18% A	8.75	2030			Plate, sheet	55–90		1–40				Fair		DD, F, R, W, B
75	Omega Nickel Silver 18% B	8.50	1930	1.02		Plate, sheet	60–125		1–40		20		Fair		F, R, W, B
76	Omega Phosphor Bronze 30	8.86	1920	0.98		Plate, sheet	45–115		5–40		16		Fair	Good	DD, F, R, W, B
77	Omega Phosphor Bronze 47	8.79	1875	1.00			51–130		1–50		14.5		Fair	Good	DD, F, R, W, B
78	Omega Phosphor Bronze 209	8.76	1830	1.00			52–135		1–70				Fair	Good	DD, F, R, W, B
79	Oxygen Free Copper	8.94	1981	0.90	0.941	Rod	30–65	12–45	5–55	60–90	16	30–110	Tough	Fair	DD, F, R, W, B
80	P M G (cast)	8.42	1868	0.96	0.083	Cast	50–60	18–20	15–35	30–50	15	100–125	Good	Good	R, W, B
81	P M G (wrought)	8.55	1868	0.96	0.083	Rod	55–150	40–110	5–60	25–70	15	60–200	Good	Good	DD, F, R, W, B
82	Phosphor Bronze 351	8.87	1922	0.95	0.195	Sheet, soft to hard	50–100	20–75	3–55		15	60–190	Fair		DD, F, R, W, B
83	Phosphor Bronze 353	8.82	1877	0.97	0.150	Sheet, soft to hard	55–110	22–70	3–70		15		Fair		DD, F, R, W, B
84	Phosphor Bronze 354	8.78	1832	0.98	0.121	Sheet, soft to hard	60–115	37–75	6–65		15		Fair		DD, F, R, W, B
85	Phosphor Bronze A	8.85	1922	0.99	0.20	Rolled strip	95	90	2		15		Fair	Good	DD, F, R, W, B
86	Phosphor Bronze A	8.84	1922	1.00		Wire, spring	135	120	1.5				Fair	Good	R, W, B
87	Phosphor Bronze C	8.81	1877	1.01	0.15	Rolled strip	110	105	2		15		Fair	Good	DD, F, R, W, B
88	Phosphorized Copper	8.94	1980	0.93	0.80	Plate, sheet, tube	32–60		4–45		17		Fair	Good	DD, F, R, W, B
89	Red Brass 85%	8.75	1868	0.98	0.38	Soft to hard	42–75	17–60	4–43		15	52–135	Fair		DD, F, R, W, B
90	Red Brass	8.64	1870	0.98	0.38	Sheet	42–83		3–47				Fair	Good	DD, F, R, W, B
91	Red Brass	8.75	1870	0.98	0.38	Rod	40–120	20–70	5–60	50–75	15	55–180	Good	Good	DD, F, R, W, B
92	Red Brass	8.72	1868	1.04	0.37	Annealed rod	40	16	55	80	15		Fair	Poor	DD, F, R, W, B
93	Resistac	7.7		0.89		Cast	75	36	18	18		100–150	Good	Good	
94	Revalon	8.31	1750–1950		0.240	Tube, soft to hard	55–85	15–70	15–50		15	75–160	Fair	Good	F, B
95	Roman Bronze	8.44	1780–1980		0.279	Rod, soft to hard	54–75	15–60	20–50		15		Fair	Fair	W, B
96	Sumet Bronze	9.13	1800–2000	1.10		Bar	21		16			33–37	Good	Good	
97	Super Nickel	8.95	2237		0.069	Sheet, soft to hard	50–75		5–40		20		Fair		DD, F, R, W, B
98	Tul-Stuf	7.6	1900	0.815		Drawn rod	75–105	45–75	10–20	20–30	15.3	170–200	Good	Good	
99	Wolverine Admiralty	8.54	1643–1715			Tube	50–95		5–60				Tough		DD, extrusion
100	Wolverine Arsenical Copper	8.93	1981	0.93	0.92	Tube	30–45		5–45	67–72	15–18	48–111	Tough		DD, extrusion
101	Wolverine Brass 70-30	8.53	1679–1728	1.04	0.29	Tube	45–70		5–65	66–75	15	53–156	Fair	Fair	DD, extrusion
102	Wolverine Comm. Bronze	8.80	1859–1922		0.44	Tube	37–75		5–47				Tough		DD, extrusion
103	Wolverine Copper, Oxygen Free	8.93	1981	0.93	0.92	Tube	30–45		5–45	67–72	15–18	48–111	Tough		DD, extrusion
104	Wolverine High Brass	8.46	1661–1706		0.36	Tube	45–89		8–56				Good		DD, extrusion
105	Wolverine Red Brass	8.72	1868	0.98	0.37	Tube	42–75		5–50	80	15		Fair		DD, extrusion

* Methods of fabrication: DD, deep drawing; F, flanging; W, welding; R, riveting; B, brazing.

ALUMINUM and ALUMINUM ALLOYS

MAKERS OF ALUMINUM AND ALUMINUM ALLOYS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Alcoa Aluminum 2S	Aluminum Co. of Amer., Pittsburgh, Pa.	Al, 99	B, CR, HR, D, P, S, R, T, W
2	Alcoa Aluminum 3S	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mn, 1.2	B, CR, HR, D, P, S, R, T, W
3	Alcoa Aluminum 43	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Si, 5	C
4	Alcoa Aluminum 52 S	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 2.5	B, CR, HR, D, P, S, R, W
5	Alcoa Aluminum 53 S-T	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 1.3; Si, 0.7; Cr, 0.25	B, HR, D, P, S, R, T, W
6	Alcoa Aluminum 214	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 3.8	C
7	Alcoa Aluminum 356-T6	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Si, 7; Mg, 0.3	C
8	40 Alloy	National Smelting Co., Cleveland, Ohio	Al; Cu, 4	C
9	40 M Alloy	National Smelting Co., Cleveland, Ohio	Al; Mg, 4	C
10	70 S Alloy	National Smelting Co., Cleveland, Ohio	Al; Si, 7.5	C
11	Aluminum 99+	National Smelting Co., Cleveland, Ohio	Al, 99+	C
12	Aluminum 98-99	National Smelting Co., Cleveland, Ohio	Al, 98-99	C
13	Permite 2019	Aluminum Industries, Inc., Cincinnati, Ohio	Al; Si, 4.5-5.5; Cu, 1-1.5; Mg, 0.4-0.6; Zn, 0.03 max.	C
14	Permite 2021	Aluminum Industries, Inc., Cincinnati, Ohio	Al; Mg, 3.25-4.25; Fe, 0.4 max.; Cu, 0.1 max.	C
15	Red X 8	National Smelting Co., Cleveland, Ohio	Al; Si, 8; Cu, 1.5; Mn, 0.5; Mg, 0.4	C
16	Red X 10	National Smelting Co., Cleveland, Ohio	Al; Si, 10; Cu, 1.5; Mn, 0.6; Mg, 0.5	C
17	Red X 13	National Smelting Co., Cleveland, Ohio	Al; Si, 13; Cu, 1.5; Mn, 0.75; Mg, 0.5	C
18	5% Silicon Alloy	National Smelting Co., Cleveland, Ohio	Al, 95; Si, 5	C
19	12% Silicon Alloy	National Smelting Co., Cleveland, Ohio	Al, 88; Si, 12	C
20	Y-Alloy	National Smelting Co., Cleveland, Ohio	Al; Cu, 4; Ni, 1.5; Mg, 1.5	C

* Forms available: B, bars; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF ALUMINUM AND ALUMINUM ALLOYS

No.	MATERIAL	Specific Gravity	Melting Point, ° F.	Mean Coeff. Therm. Exp., 32-212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Alcoa Aluminum 2S	2.71		1.3	0.52	Cold rolled sheet	24	21	5		10	44	Fair	Fair	DD, F, R, W
					0.54	Annealed sheet	13	5	35		10	23			
2	Alcoa Aluminum 3S	2.73		1.3	0.37	Hard rolled sheet	29	25	4		10	55	Fair	Fair	DD, F, R, W
					0.45	Annealed sheet	16	6	30		10	28			
3	Alcoa Aluminum 43	2.68		1.2	0.34	Cast	17	9	3		10	40	Fair	Fair	
4	Alcoa Aluminum 52S	2.67		1.3	0.37	Hard rolled sheet	41	36	7		10	85	Good	Good	F, R, W
						Annealed sheet	29	14	25		10	45			
5	Alcoa Aluminum 53 S-T	2.69		1.3	0.37	Sheet	39	33	14		10	80	Good	Good	F, R, W
6	Alcoa Aluminum 214	2.63		1.3	0.32	Cast	22	12	6		10	50	Good	Good	
7	Alcoa Aluminum 356-T6	2.65		1.2	0.36	Cast	30	22	3		10	70	Good	Good	
8	40 Alloy	2.77	1100-1200	1.27	0.35	Heat treated	30-40	15-35	1-10		10	50-110	Good		
9	40 M Alloy	2.63	1100-1200	1.33	0.32	Cast	26	13	9			50	Fair	Fair	
10	70 S Alloy	2.65	1070-1130	1.2	0.40	Heat treated	28-40	26-38	1-5			70-90	Fair	Fair	
11	Aluminum 99+	2.72	1214	1.33	0.52	Cast	12		40			18	Poor	Poor	
12	Aluminum 98-99		1070-1200		0.50	Cast	12					18	Poor	Poor	
13	Permite 2019	2.69	1075-1160	1.30		Cast	32	27	2			70-90	Good		
14	Permite 2021	2.68	1075-1185	1.44		Cast	22	12	6			45-60	Fair		
15	Red X 8	2.70	1070-1150	1.165	0.33	Heat treated	30-45	28-43	0-5		10	80-130	Good	Good	
16	Red X 10	2.70	1070-1100	1.13	0.30	Heat treated	33-48	33-45	1		10	100-140	Good	Good	
17	Red X 13	2.70	1070-1100	1.08	0.28	Heat treated	36-48	30-45			10	100-150	Good	Good	
18	5% Silicon Alloy	2.66	1070-1250	1.25	0.44	Cast	20	10	4			40	Fair	Fair	
19	12% Silicon Alloy	2.64	1070	1.14	0.36	Cast	26	11	7			50	Fair	Fair	
20	Y-Alloy	2.73	1100-1200	1.3	0.35	Cast	30-50	28-45	0-3		10	80-150	Good	Good	

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding.

LEAD and ITS VARIOUS ALLOYS

MAKERS OF LEAD AND LEAD ALLOYS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Antimonial Lead	Andrews Lead Co., Long Island City, N. Y.	Pb; Sb, 3-8	B
2	Antimonial Lead	Eagle-Picher Co., Cincinnati, Ohio	Pb; Sb, 3-8	C, S, T, W
3	Antimonial Lead	Flemm Lead Co., Long Island City, N. Y.	Pb; Sb, 3-8	S, T, W, B
4	Antimonial Lead 6%	National Lead Co., New York, N. Y.	Pb, 94; Sb, 6	B, C, S, R, T, W, Rolled
5	Antimonial Lead	Northwest Lead Co., Seattle, Wash.	Pb, 92-96; Sb, 4-8	B, C, S, T, W
6	Asarco Acid Lead	American Smelting & Refining Co., New York, N. Y.	Pb, 99.92; Bi, 0.019; Ag, 0.0004; Cu, 0.06; Fe, 0.0001; Cd, 0.0002	B, CR, HR, S, T, W, Pipe

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; S, sheets; R, rods; T, tubes; W, wire.

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
7	Chemical Lead	Andrews Lead Co., Long Island City, N. Y.	Pb, 99.8 plus	B
8	Chemical Lead	Eagle-Picher Co., Cincinnati, Ohio	Pb, 99.8 plus	C, S, T, W
9	Chemical Lead	Flemm Lead Co., Long Island City, N. Y.	Pb, 99.8 plus	S, T, W, B
10	Chemical Lead	National Lead Co., New York, N. Y.	Pb; Cu, 0.04–0.08; F ,0.0002; Ni & Co, 0.0048; Ag, 0.0068	B, C, S, R, T, W, Rolled
11	Chemical Lead	Northwest Lead Co., Seattle, Wash.	Pb, 99.95; Cu, 0.05	B, C, S, T, W
12	Tellurium-Antimonial Lead	Andrews Lead Co., Long Island City, N. Y.	Pb; Sb; Te, 0.1 max.	S, T, B
13	Tellurium-Antimonial Lead	Northwest Lead Co., Seattle, Wash.	Pb; Sb, 4–6; Te, 0.06	
14	Tellurium Lead	Andrews Lead Co., Long Island City, N. Y.	Pb; Te, 0.04–0.10	S, T, B
15	Tellurium Lead	Eagle-Picher Co., Cincinnati, Ohio	Pb; Te, 0.04–0.10	S, T
16	Tellurium Lead	National Lead Co., New York, N. Y.	Pb; Te, 0.04–0.05; Cr, 0.04–0.08; Ni & Co, 0.0048; Ag, 0.0068	B, C, S, R, T, W, Rolled
17	Tellurium Lead	Northwest Lead Co., Seattle, Wash.	Pb, 99.89; Te, 0.06; Cu, 0.05	B, C, S, R, T, W, Rolled

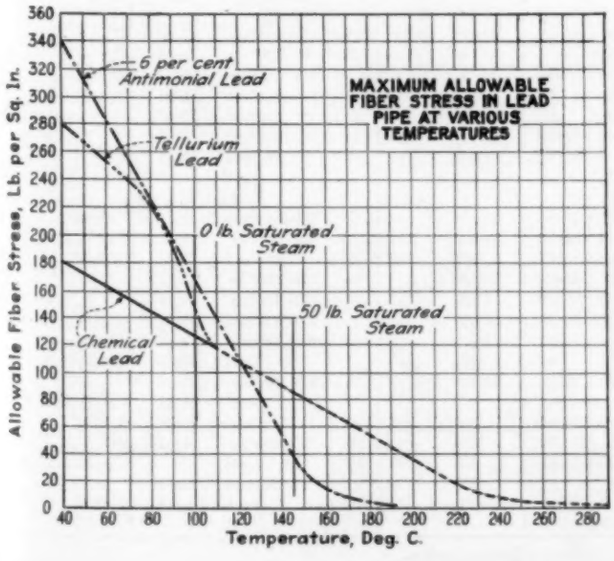
* Forms available: B, bars; C, castings, CR, cold rolled; HR, hot rolled; S, sheets, R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF LEAD AND LEAD ALLOYS

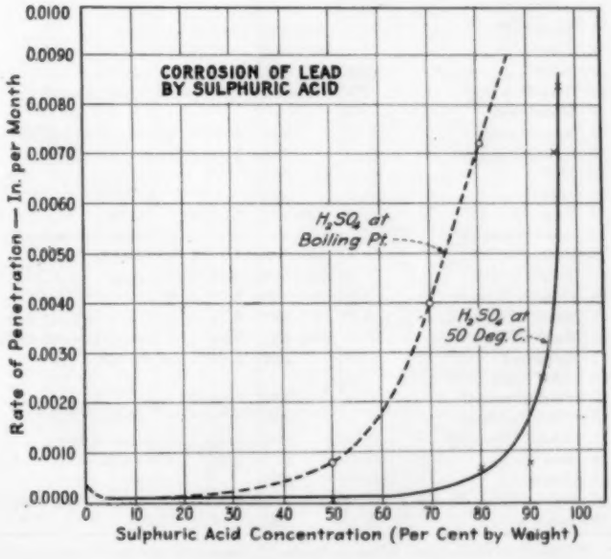
No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coefl. Therm. Exp., 32–212°F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Elastic Modulus, Lb. per in.² Multiply by 10^6	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication**
1	Antimonial Lead	10.8	477–545	1.52	0.068	Rolled	4	3	39	2	9	Good		F, W
2	Antimonial Lead	10.8	477–545	1.52	0.068	Rolled	4	3	39	2	9	Good		F, W
3	Antimonial Lead	10.8	477–545	1.52	0.068	Rolled	4	3	39	2	9	Good		F, W
4	Antimonial Lead 6%	11.0	477–554	1.4	0.069	Rolled sheet	4	2	45	2	8	Good		F, W
5	Antimonial Lead	11.38	585–610	1.50	0.082	Rolled sheet	3–3.2	1.6	75			Good		W
6	Asarco Acid Lead	11.34	619	1.6		Rolled strip	2.25	0.975		2	4.5	Good		
7	Chemical Lead	11.3	610–620	1.63	0.083		1.9–2.3	0.7	50	1–2	4.5–5.5	Good		F, W
8	Chemical Lead	11.3	610–620	1.63	0.083		1.9–2.3	0.7	50	1–2	4.5–5.5	Good		F, W
9	Chemical Lead	11.3	610–620	1.63	0.083		1.9–2.3	0.7	50	1–2	4.5–5.5	Good		F, W
10	Chemical Lead	11.36	617	1.6	0.083	Sheet	2.4	1.2	40	1.5	4.5–6.0	Good		F, W
11	Chemical Lead	11.38	620	1.61	0.082	Rolled	1.74	1.0	50		4.5–6	Good		W
12	Tellurium-Antimonial Lead													
13	Tellurium-Antimonial Lead													
14	Tellurium Lead	11.35	620	1.63	0.083		2.8–4		30–50	1–2	5–6	Good		F, W.
15	Tellurium Lead	11.35	620	1.63	0.083		2.8–4		30–50	1–2	5–6	Good		F, W
16	Tellurium Lead	11.32	617	1.6	0.083	Rolled sheet	3	1.5	40	1.5	5–6.5	Good		F, W
17	Tellurium Lead	11.32	617	1.6	0.083	Rolled sheet	3	1.5	40	1.5	5–6.5	Good		F, W

** Methods of fabrication: F, flanging; W, welding (burning).

The formula for safe working pressure in pipe at various temperatures is P = 2 ST/D, where P is safe working pressure in lb. per sq.in., S is maximum allowable fiber stress (from graph) T is thickness of pipe wall in inches, and D is inside diameter in inches



Results shown below were obtained by measuring loss of weight of a lead sample suspended in acid. The sample was removed from solution daily for 14 days and examined after dissolving the sulphate coating in ammonium acetate solution



NICKEL and HIGH-NICKEL ALLOYS

MAKERS OF NICKEL ALLOYS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	A-Alloy, Grade A	General Alloys Co., Boston, Mass.	Ni, 66–68; Cr, 19–21; Mn, 0.5–1.0; C, 0.4–0.8; Fe, bal.	B, C, P, R
2	D. H. 99	Driver-Harris Co., Harrison, N. J.	Ni, 99.0	HR, CR, D, P, S, W, B
3	Durco D-10	Duriron Co., Dayton, Ohio	Ni, 57; Cr, 23; Cu, 8; Mo, 4; W, 2; Mn, 1	C
4	G-60	La Bour Co., Elkhart, Ind.	Ni, 63Cr, 24; Cu, 5; Mo, 4; W, 2; Si, 0.80; Fe, 1	C
5	Hastelloy A	Haynes Stellite Co., Kokomo, Ind.	Ni; Mo; Fe	B, C, HR, P, S, R, T, W
6	Hastelloy B	Haynes Stellite Co., Kokomo, Ind.	Ni; Mo; Fe	B, C, HR, P, S, R, T, W
7	Hastelloy C	Haynes Stellite Co., Kokomo, Ind.	Ni; Mo; Cr; Fe	B, C
8	Hastelloy D	Haynes Stellite Co., Kokomo, Ind.	Ni; Si	B, C
9	Illium G	Burgess-Parr Co., Freeport, Ill.	Ni, 55–60; Cr, 18–24; Mo, 5–7, Fe; 4–8; Cu, 1–8; Mn, 1–1.5; Si, 0.5–0.8; C, 0.2	B, C, P, R, T
10	Illium R	Burgess-Parr Co., Freeport, Ill.	Ni, 60–64; Cr, 18–24; Fe; 5–10; Mo, 3–6; Cu, 1–5; Mn, 0.4–0.6; Si, 0.3–0.5	B, C, CR, P, S, R, T, W
11	Inconel (cast)	International Nickel Co.; New York, N. Y.	Ni, 77.85; Cr, 13.5; Fe, 6; Si, 1.5;Mn, 0.75; Cu, 0.2; C, 0.2	C
12	Inconel (wrought)	International Nickel Co., New York, N. Y.	Ni, 79.5; Cr, 13; Fe, 6.5; Mn, 0.25; Si, 0.25; Cu, 0.2; C, 0.08	B, CR, HR, D, P, S, R, T, W
13	Inconel-Clad Steel	Lukens Steel Co., Coatesville, Pa.	Ni, 79.5; Cr, 13; Fe, 6.5; Mn, 0.25; Si, 0.25; C, 0.08†	HR, P
14	Jelliff A	C. O. Jelliff Mfg. Corp., Southport, Conn.	Ni, 80; Cr, 20	
15	Jelliff C	C. O. Jelliff Mfg. Corp., Southport, Conn.	Ni, 64; Cr, 15	
16	Monel (cast)	International Nickel Co., New York, N. Y.	Ni, 67; Cu, 30; Fe, 1.5; Si, 1.25; Mn, 0.25; C, 0.2	C
17	Monel (Wrought)	International Nickel Co., New York, N. Y.	Ni, 67; Cu, 30; Fe 1.4; Mn, 1	B, CR, HR, D, P, S, R, T, W
18	Monel-Clad Steel	Lukens Steel Co., Coatesville, Pa	Ni, 67; Cu, 30; Fe, 1.4; Mn, 1; C, 0.15; Si, 0.1†	HR, P
19	Monel H (cast)	International Nickel Co., New York, N. Y.	Ni, 66; Cu, 29; Fe, 1.5; Si, 3; Mn, 0.3; C, 0.2	C
20	Monel K (wrought)	International Nickel Co., New York, N. Y.	Ni, 66; Cu, 29; Al, 2.75; Fe, 0.9; Mn, 0.4; Si, 0.25; C, 0.15	B, CR, HR, D, R, W
21	Monel R (wrought)	International Nickel Co., New York, N. Y.	Ni, 67; Cu, 30; Fe, 1.7; Mn, 1.1; C, 0.1; Si, 0.05; S, 0.035	B, HR, D, R, W
22	Monel S (cast)	International Nickel Co., New York, N. Y.	Ni, 65; Cu, 29; Si, 4; Fe, 2; Mn, 0.3; C, 0.2	C
23	Nichrome V	Driver-Harris Co., Harrison, N. J.	Ni, 80; Cr, 20	C, CR, HR, D, P, S, T, W, B
24	Nickel (cast)	International Nickel Co., New York, N. Y.	Ni, 96.7; Si, 1.5; Fe, 0.5; Mn, 0.45; C, 0.5	C
25	Nickel (wrought)	International Nickel Co., New York, N. Y.	Ni, 99.4; Mn, 0.2; Fe, 0.15; Cu, 0.1; C, 0.1; Si, 0.05	B, CR, HR, D, P, S, R, T, W
26	Nickel-Clad Steel	Lukens Steel Co., Coatesville, Pa.	Ni, 99.4; Mn, 0.2; Fe, 0.15; Cu, 0.1; C, 0.1; Si, 0.05†	HR, P
27	Nickel Z (wrought)	International Nickel Co., New York, N. Y.	Ni, 98.85; Fe, 0.1; Mn, 0.1; Si, 0.1; Cu, 0.03	B, CR, HR, D, R, T, W
28	Nirex	Driver-Harris Co., Harrison, N. J.	Ni, 80; Cr, 14; Fe, 6	HR, CR, D, P, S, T, W, B
29	Pioneer	Pioneer Alloy Products Co., Cleveland, Ohio	Ni, 65; Cr; Mo; Fe	
30	Superior Nickel Chrome	Alloy Metal Wire Co., Prospect Pk., Pa.	Ni, 80; Cr, 20	CR, R, W
31	Tophet A	Wilbur B. Driver Co., Newark, N. J.	Ni, 80; Cr, 20	W, ribbon

* Forms available: B, bars; C castings; CR,, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire. † Applies to cladding only.

PHYSICAL PROPERTIES OF NICKEL ALLOYS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. (Multiply by 10⁶)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10⁶)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	A-Alloy, Grade A	8.05	2700–2800	0.71	0.014	Cast	60–80	40–50	4	3	30	217	Good	Good	W
2	D. H. 99	8.90	2642	0.70	0.15	Wrought	60–100	25–75	30–35	50–65			Good	No	DD, F, R, W, B
3	Durco D-10	8.2	2500	0.78		Cast	65	45	5	5		175	Fair	Fair	
4	G-60												Fair	Yes	R, W, B.
5	Hastelloy A	8.80	2372–2426	0.61	0.04										
6	Hastelloy B	9.24	2408–2462	0.56	0.027	Rolled annealed	130–140	60–65	40–45	40–45	30.8	210–235	Fair	Fair	D, R, W
						Cast	75–82	55–57	6–9	10–13		190–230			
7	Hastelloy C	8.94	2318–2381	0.63	0.03	Cast	72–80	45–48	10–15	11–16	28.5	175–215	Fair	Fair	W
8	Hastelloy D	7.80	2030–2048	0 61	0.05	Cast	36–40.5		0	0	28.9	50–55†	Poor	Good	W
9	Illium G	8.3	2300–2400			Cast	68	50	30–35			170–220	Fair	Good	W
10	Illium R	8.3	2300–2400	0.51		Rolled, annealed	100	50	30–35			215–240	Fair	Good	DD, W
11	Inconel (cast)	8.55					85	50	10		31	200	Poor	Good	
12	Inconel (wrought)	8.55	2540	0.64	0.035	Annealed to hardened	80–185	25–165	2–55		31	110–340	Fair	Good	DD, F, R, W, B
13	Inconel-Clad Steel	8.55	2540	0.64	0.035	As rolled, plate	55 min.	27.5 min.	30	45	29.3	130	Good	Good	F, R, W
14	Jelliff A	8.42	2550			Annealed	120								
15	Jelliff C	8.24	2460			Annealed	100								
16	Monel (cast)	8.80	2400–2450	0.68	0.06	As cast	65–80	32.5–40	25–45		26	125–150	Fair	Good	
17	Monel (Wrought)	8.80	2370–2460	0.78	0.06	Annealed to hardened	65–170	25–150	2–50			120–290	Fair	Good	DD, F, R, W, B
18	Monel-Clad Steel	8.85	2370–2460	0.78	0.06	As rolled, plate	55 min.	27.5	30	45	29.3	125	Good	Good	F, R, W
19	Monel H (Cast)	8.80	2350–2400	0.68	0.06	As cast	70–90	45–65	10–20		26	175–250	Poor	Good	
20	Monel K (Wrought)	8.60	2400–2460	0.78	0.043	Annealed to hardened	90–200	50–160	3–50		26	120–350	Fair	Good	DD, F, R, W, B
21	Monel R (Wrought)	8.80	2370–2460	0.78	0.06	H.R. rod to C.D. wire	75–115	35–90	5–45		26	130–240	Good	Good	Machining
22	Monel S (Cast)	8.80	2300–2350	0.68	0.06	Annealed to heat treated	90–115	70–90	1–3		26	275–350	Poor	Good	
23	Nichrome V	8.41	2552	0.73	0.036	Wrought	110	60	35	55			Good	No	DD, F, R, W, B
24	Nickel (Cast)	8.85					55–70	20–35	15–30		30	100–130	Fair	Good	
25	Nickel (Wrought)	8.85	2640	0.72	0.14						30		Fair	Good	DD, F, R, W, B
26	Nickel-Clad Steel	8.85	2640	0.72	0.14	As rolled, plate	55 min.	27.5 min.	30	45	29.3	120	Good	Good	F, R, W
27	Nickel Z (Wrought)	8.85	2640	0.72	0.14	Annealed rod	90	35	50		30	150	Fair	Good	DD, F, R, W, B
28	Nirex	8.53	2516	0.70		Wrought	80–150	40	45	60			Good	No	DD, F, R, W, B
29	Pioneer	7.83	2750			Cast	74	36.5	42			150	Good	Good	
30	Superior Nickel Chrome	8.40		0.94	0.149	Annealed wire, rod, strip	100	35–40	35–40	75			Poor	Good	F, R, W
31	Tophet A	8.42	2200	0.73		Wire	80–200								

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brasing. † Rockwell C hardness number.

MAKERS AND PHYSICAL PROPERTIES OF SILVER

MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Specific Gravity	Melting Point, °F.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Rockwell B Hardness
Coin Silver	Handy & Harman, New York, N. Y.	Ag, 90; Cu 10	10.35	1435–1615	Hard	70–75	60–65	5– 7	80–90
					Annealed	35–40	25–30	30–35	30–40
	American Platinum Works, Newark, N. J.								
	Baker & Co., Newark, N. J.								
	J. Bishop & Co., Malvern, Pa.								
Fine Silver	Handy & Harman, New York, N. Y.	Ag,99.9+	10.53	1762	Hard	41	35–40	6–10	50–56
					Annealed	23	15–20	40–50	5–15
	American Platinum Works, Newark N. J.								
	Baker & Co., Newark, N. J.								
	J. Bishop & Co., Malvern, Pa.								
Sterling Silver	Handy & Harman, New York, N. Y.	Ag, 92.5; Cu, 7.5	10.40	1435–1635	Hard	67–72	55–60	4–6	75–85
					Annealed	35–40	20–25	30–35	25–40
	American Platinum Works, Newark, N. J.								
	Baker & Co., Newark, N. J.								
	J. Bishop & Co., Malvern, Pa.								
Silver-Clad Copper	Handy & Harman, New York, N. Y.	Tensile properties same as copper							
Silver-Clad Nickel	Handy & Harman, New York, N. Y.	Tensile props. slightly greater than nickel portion							
Silver-Clad Steel	Handy & Harman, New York, N. Y.	Ag, 10–16; Bal., SAE 1020 steel. Tensile props. slightly greater than steel portion							

Corrosion Resistance of Fine Silver

A NUMBER OF CORRODING AGENTS whose action on silver has been reported in the literature are listed below. The asterisk (*) indicates that the resistance of commercial fine silver was found satisfactory under the reported test conditions. In the absence of the asterisk it may be assumed that the agent in question attacks silver materially.

This listing does not constitute a recommendation; the selection of corrosion-resisting material should be based ultimately on service tests as it is impossible to predict accurately from laboratory tests or simulated service tests what actual corrosion in a particular service may be.

* Acetate Rayon
* Acetic Acid
* Acetic Anhydride
* Acetone
* Acetyl Salicylic Acid
Acetylene
Alkali Cyanides
Alkali Sulphides
* Alum
* Aluminum Sulphate
* Ammonia
* Ammonium Carbonate
* Ammonium Chloride
* Ammonium Hydroxide
Ammonium Hydroxide—chloride mixture
Ammonium Polysulphide
* Ammonium Sulphate (Sat.) plus 5% Sulphuric Acid
* Aniline Dyes
* Aqua Regia
* Arsenic Acid Solution
* Artificial Silk Industry (See Acetate Rayon)
* Atmosphere
Barium Peroxide
Benzaldehyde
* Benzoic Acid
* Beverages
* Bismuth Oxide
Bleaching Powder
Borax, fused
* Boric Acid
* Brewery Fluids
* Brom-fluoride
Bromic Acid
Bromine
Bromine Vapor-Moisture
* Caesium Hydroxide
* Carbolic Acid
* Carbon Dioxide
* Carbon Disulphide
Carbon Monoxide
* Carbon Tetrachloride
* Carbonic Acid
p-Chlorbenzaldehyde
Chlorates (Alkali metals)
Chloric Acid
* Chlorine
* Chlorine Vapor-Moisture
Chromic Acid
* Cider
* Citric Acid
* Coal Tar Products
* Cupric Chloride, cold
Cupric Nitrate
Cupric Sulphate
* Cupric Sulphate (10%)+2% Sulphuric Acid
Suprous Chloride
* Cupric Oxide
* Cyanogen
* Dairy Equipment
* Dyestuffs
* Essential Oils
* Ether, Ethyl
* Ethyl Chloride
* Fatty Acids
Ferrous Ammonium Sulphate
Ferrous Sulphate
Ferric Sulphate
* Fluorides
* Fluorine
* Foodstuffs
* Formaldehyde
* Formic Acid
* Fruit Juices and Extracts
* Gelatin
* Glue
* Glycerin
* Halogen Gases
Hydriodic Acid
Hydrobromic Acid
* Hydrochloric Acid, dilute
* Hydrofluoric Acid
* Hydrogen
* Hydrogen Chloride
Hydrogen Peroxide
Hydrogen Selenide
Hydrogen Sulphide
Hypochlorous Acid
* Ink
Iodic Acid
* Iodine Solution
Iodine in Potassium Iodide
* Iron Oxide
* Jellies
* Lactic Acid
* Lead Oxide
Lead Peroxide
* Leaded Gasoline
* Lead Halides
* Magnesium Chloride
* Magnesium Sulphate
* Malic Acid
* Marmalade
Mercuric Chloride
Mercuric Iodide
Mercuric Nitrate
Mercurous Chloride
Mercury
* Methyl Salicylate
Mixed (Nitric-Sulphuric) Acid
Nitric Acid
* Nitric Oxide
* Nitrogen
Nitrogen Tetroxide
* Nitrosylchloride
* Oleic Acid
* Organic Acids
* Oxalic Acid
* Oxygen
* Ozone
* Palmitic Acid
* Pectin
Persulphate Solutions
* Pharmaceuticals
* Phenol
* Phosphates
* Phosphoric Acid
* Phosphoric-Hydrochloric Acids
* Photographic Emulsions
Potassium Bromide, molten
* Potassium Chloride, solution
Potassium Cyanide
* Potassium Dichromate
Potassium Ferrocyanide
* Potassium Hydroxide
Potassium Iodide, molten
Potassium Nitrate, molten
Potassium Permanganate
Potassium Peroxide
Potassium Persulphate
Potassium Sulphide
* Propionic Acid
Pyrosulphuric Acid
* Pthalic Acid
* Rayon
* Rubidium Hydroxide
* Sea Water
Selenic Acid
* Sodium Bicarbonate
Sodium Bicarbonate, fused
* Sodium Borate
Sodium Bromide, fused
* Sodium Carbonate
* Sodium Chloride
Sodium Chloride, fused
Sodium Cyanide
Sodium Ferrocyanide
* Sodium Hydroxide
Sodium Iodide, fused
* Sodium Metaphosphate
* Sodium Nitrate Solution
Sodium Nitrate, fused
Sodium Poly-sulphide
Sodium Peroxide
* Sodium Phosphate, dibasic
* Sodium Phosphate, mono-basic
Sodium Phosphate, fused
* Sodium Sulphate
Sodium Sulphide
Sodium Thio-sulphate
* Stearic Acid
Sulphur
Sulphur Dioxide
Sulphur Monochloride
Sulphur Trioxide
* Sulphuric Acid (under 60%)
* Sulphurous Acid
* Sulphuryl Chloride
* Tanning Industry
* Tartaric Acid
* Tetraethyl Lead
p-Toluyladehyde
* Urea
* Vinegar
Viscose
* Water
* Water Vapor
* Wines
* Zinc Chloride
* Zinc Oxide

NOBLE METALS and THEIR ALLOYS

MAKERS AND PHYSICAL PROPERTIES OF NOBLE METALS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Specific Gravity	Melting Point, ° F.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Elongation, % in 2 in.	Brinell Hardness	Machining Qualities	Abrasion Resistance	Forms Available*
1	Fine Gold	Baker & Co., Newark, N. J.	Au, 99.99	19.3	1945	Annealed	14	45	35	Poor	Poor	B, C, CR, HR, D, P, S, R, T, W
2	Gold-Platinum	Baker & Co., Newark, N. J.	Au, 70; Pt, 30	19.9	2160-2590	Annealed	65		135	Good	Good	
3	Iridioplatinum	Baker & Co., Newark, N. J.	Pt, 70; Ir, 30	21.7	3620	Annealed	160		280	Good	Good	B, C, CR, HR, S, R, W
4	Iridio Platinum	J. Bishop & Co., Malvern, Pa.	Pt, 75; Ir, 25	20.9		Annealed wire	133	20	185			B, C, CR, HR, D, P, S, R, T, W
5	Iridioplatinum	Baker & Co., Newark N. J.	Pt. 80; Ir, 20	21.6	3410	Annealed	100	20	200	Good	Good	B, C, CR, HR, D, P, S, R W
6	20% Iridio Platinum	J. Bishop & Co., Malvern, Pa.	Pt, 80; Ir, 20	21.7	3353	Annealed wire	103	20	150			B, C, CR, HR, D, P, S, R, T, W
7	15% Iridio Platinum	J. Bishop & Co., Malvern, Pa.	Pt, 85; Ir, 15	21.6	3344	Annealed wire	80	20	103			B, C, CR, HR, D, P, S, R, T, W
8	Iridioplatinum	Baker & Co., Newark, N. J.	Pt, 90; Ir, 10	21.5	3300	Annealed	55	30	130	Good	Good	B, C, CR, HR, D, P, S, R, T, W
9	10% Iridio Platinum	J. Bishop & Co., Malvern, Pa.	Pt, 90; Ir, 10	21.5	3290	Annealed wire	67	25	92			B, C, CR, HR, D, P, S, R, T, W
10	5% Iridio Platinum	J. Bishop & Co., Malvern, Pa.	Pt, 95; Ir, 5	21.6	3218	Annealed wire	39	32	56			B, CR, D, P, S, R, T, W
11	Iridium	Baker & Co., Newark, N. J.	Ir, 99.8	22.4	4450	Annealed			172	Fair	Good	B, C, S
12	Osmium	Baker & Co., Newark, N. J.	Os, 99.5+	22.5	4900					Poor	Good	B, C
13	Palladium	Baker & Co., Newark, N. J.	Pd, 99.5+	12	2830	Annealed	20	40	49	Poor	Poor	B, CR, HR, D, P, S, R, T, W, C
14	Palladioplatinum	Baker & Co., Newark, N. J.	Pt, 80; Pd, 20	18.3	3145	Annealed	50		94	Fair	Fair	B, CR, HR, D, P, S, R, T, W, C
15	Platinum, C. P.	Baker & Co., Newark, N. J.	Pt, 99.99	21.5	3223	Annealed	18	44	47	Poor	Fair	B, CR, HR, D, P, S, R, T, W, C
16	Platinum, C. P.	J. Bishop & Co., Malvern, Pa.	Pt, 99.9	21.4	3191	Annealed	23	50	35			B, CR, HR, D, P, S, R, T, W
17	Platinum, Comm.	Baker & Co., Newark, N. J.	Pt, 99.0+	21.4	3223	Annealed	21	37	50	Poor	Fair	B, C, CR, HR, D, P, S, R, T, W
18	Platinum-Gold	Baker & Co., Newark, N. J.	Pt, 90; Au, 10	21.3	2950-3125	Annealed	80	16	150	Good	Good	B, C, S, R, W
19	Rhodioplatinum	Baker & Co., Newark, N. J.	Pt, 90; Rh, 10	20.0	3350	Annealed	45	40	90	Good	Fair	B, C, CR, HR, D, P, S, R, T, W
20	Rhodium	Baker & Co., Newark, N. J.	Rh, 99.8+	12.4	3570	Annealed	135			Poor	Fair	B, C, CR, HR, S, R, W
21	10% Rhodium	J. Bishop & Co., Malvern, Pa.	Pt, 90; Rh, 10	20.2	3310	Annealed wire	47	37	69			B, C, CR, HR, D, P, S, R, T, W
22	Ruthenium	Baker & Co., Newark, N. J.	Ru, 99.5	12.2	4440	Cast			220	Poor	Good	B, C

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

ACTION OF CHEMICALS ON PRECIOUS METALS AND THEIR ALLOYS

Key to Table: — A = unattacked, B = slightly attacked, C = moderately attacked, and D = strongly attacked.

Chemical	C.P. Pt	Comm. Pt	Pd	Rh	Ir	Os	Ru	Au	90 Pt–10 Rh	90 Pt–10 Ir	80 Pt–20 Ir	70 Pt–30 Ir	80 Pt–20 Pd	90 Pt–10 Au	70 Au–30 Pt
HCl, 30–110 °C	A	A	B	A	A	A	A	A	A	A	A	B	A	A	A
H_2SO_4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
H_2SO_4, 100 °C	A	A	B	B	A	A	A	A	A	A	A	B	A	A	A
H, SO_4, 250 °C	B	B	C	B	A	B	A	A	B	B	B	B	B	A	A
H NO_3	A	A	C	A	A	C	A	A	A	A	A	B	A	A	A
HNO_3, 120 °C	A	A	D	A	A	D	A	A	A	A	A	C	A	A	A
HF, aq	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Aqua Regia	D	D	D	A	A	A	A	D	C	B	A	A	D	D	D
Aq. Reg. at b.p.	D	D	D	B	A	C	B	D	D	C	B	A	D	D	D
Acetic Acid	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Acetic, 118°C.	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

Chemical	C.P. Pt	Comm. Pt	Pd	Rh	Ir	Os	Ru	Au	90 Pt–10 Rh	90 Pt–10 Ir	80 Pt–20 Ir	70 Pt–30 Ir	80 Pt–20 Pd	90 Pt–10 Au	70 Au–30 Pt
Tartaric Acid	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Oxalic Acid	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Cl, dry	A	A	C	A	A	A	A	D	A	A	A	A	B	B	C
Br, dry	A	A	C	A	A	A	A	D	A	A	A	A	B	B	C
KHS O_4	B	B	C	C	A	B	B	B	B	B	B	B	B	B	B
NaOH, aq	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
KOH, aq	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
NH_4OH, aq	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
NaOH, fused	B	B	B	A	A	C	C	B	A	A	A	A	B	B	B
KOH, fused	B	B	B	A	A	C	C	B	A	A	A	A	B	B	B
Na_2CO_3, fused	A	A	B	A	A	B	B	A	A	A	A	A	B	B	B

TANTALUM and ITS ALLOYS

MAKERS OF TANTALUM AND TANTALUM CARBIDE

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Tantalum	Fansteel Metallurgical Corp., North Chicago, Ill.	Ta, 99.9 +	CR, D, S, R, T, W
2	Vascoloy-Ramet	Vascoloy-Ramet Corp., North Chicago, Ill.	Tantalum carbide	Blanks, shapes

* Forms available: CR, cold rolled; D, drawn; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF TANTALUM AND TANTALUM CARBIDE

No.	MATERIAL	Specific Gravity	Melting Point, ° F.	Mean Coef. Therm. Exp., 32–212° F. (Multiply by 10^6)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Tantalum	16.6	5160	0.357	0.130	Annealed sheet	57	51	25–40		90	Good	Poor	DD, F, W
2	Vascoloy-Ramet	15.5		0.34	0.06					56	†90	Unmachinable	Good	B

* Methods of fabrication: DD, deep drawing; F, flanging; W, welding; B, brazing. † Rockwell "A" hardness number.

4-10 CHROMIUM STEEL ALLOYS

MAKERS OF 4 TO 10 CHROMIUM STEELS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Alcrosil 5	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; Cr, 4-6; C, 0.15 max.; Mn, 0.50 max.; Si, 0.75-1.25; Al, 0.50-0.60	B, HR, D, T
2	4-6 Chrome	Spang Chalfant Div., Nat. Supply Co., Pittsburgh, Pa.	Fe; Cr, 4-6; C, 0.10 max.; Mn, 0.5 max.; Mo, 0.45-0.65; Ti, 4-6 × C	HR, T
3	4-6 Chrome	Spang Chalfant Div., Nat. Supply Co., Pittsburgh, Pa.	Fe; Cr, 4-6; C, 0.20 max.; Mn, 0.5 max.; Mo, 0.45-0.65; Si, 0.5 max.	HR, T
4	5% Chrome-Moly	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; Cr, 4-6; C, 0.15 max.; Mn, 0.50 max.; Mo, 0.45-0.65; Si, 0.50 max.	HR, D, T
5				
6	Circle L 10	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 5; C, 0.20; Mo, 0.50	C
7	Cooper 5	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 4-6; C, 0.20; Mn, 0.50; Mo, 0.4-0.65	C
8	Crane 5	Crane Co., Chicago, Ill.	Fe: Cr, 5-5; C, 0.30 max.; Mo., 0.55	C
9	Croloy 5	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 4-6; C, 0.1; Mo, 0.5	CR, HR, T
10	Croloy 9	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 8-10; C, 0.1; Mo, 1.5	CR, HR, T
11	Empire 18	Empire Steel Castings, Inc., Reading, Pa.	Fe; Cr, 4-6; C, 0.25 max.; Mn, 0.4-0.5	C
12	Endure 4-6% Cr (501)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 4-6; C, over 0.10; Mn, 0.50; Mo, 0.4-0.6 (optional)	B, C, CR, HR, D, P, S, R, T, W
13	Endure 4-6% Cr (502)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 4-6; C, 0.10 max.; Mn, 0.50; Mo; 0.4-0.6 (optional)	B, C, CR, HR, D, P, S, R, T, W
14	Genesee 255	Symington-Gould Corp., Rochester, N. Y.	Fe; Cr, 5; C, 0.20; Mn, 0.70; Mo, 0.50	
15	Lo Cro 46	Crucible Steel Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.25 max.	
16	Lo Cro 46 Mo	Crucible Steel Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.25 max.; Mo, 0.40-0.60	
17	Lo Cro 46 W	Crucible Steel Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.25 max.; W, 0.75-1.25	
18	Sicromo 5	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; Cr, 4-6; C, 0.15 max.; Mn, 0.50 max.; Mo, 0.45-0.65; Si, 1-2	B, HR, D, S, T
19	Sivyer 5% Cr	Sivyer Steel Castings Co., Milwaukee, Wis.	Fe; Cr, 4.5-6.5; C, 0.25 max.; Mo, 0.45-0.65	C
20	Tisco 53	Taylor-Wharton Iron & Steel Co., High Bridge, N. J'	Fe; Cr, 5; C, 0.25; Mn, 0.60; Mo, 0.50	C
21	Warman 5M	Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 5-7; C, as specified; Mo, 0.50-0.60	C

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF 4 TO 10 CHROMIUM STEELS

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. Multiply by 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Alcrosil 5					Annealed	70	40	40			156			F, W
2	4-6 Chrome					Drawn	66	39	45		30	143	Good	Fair	F, W
3	4-6 Chrome			0.63		Annealed	67	26	39	81	30	128	Good	Fair	F, W
4	5% Chrome-Moly					Annealed bar	66	26	39	80		128			F, W
5	Circle L 10			0.62	0.093	Air quenched & drawn	100	75	18	30		215	Good	Fair	
6	Cooper 5	7.83	2700	0.66	0.11	Cast	100	80	15	25	28	220	Good	Good	
7	Crane 5					Cast & heat treated	110	80	18	30		220-245			
8	Croloy 5	7.8	2750	0.65	0.105	Annealed tube	60	25	30	70	30	263	Good	Fair	F, W
9	Croloy 9	7.8	2600-2650	0.63		Annealed tube	70 min.	30 min.	28 min.			180 max.	Good	Fair	F, W
10	Empire 18					Annealed casting	85	50	15-25	30-35		200	Fair	Fair	W
11	Endure 4-6% Cr (501)	7.83	2700-2800				65-70	25-30	34	75	30	131			
12	Endure 4-6% Cr (502)	7.83	2700-2800				65-70	25-30	34	75	30	131			
13	Genesee 255	7.78					110	80	20-25	50-55		180-200	Fair		
14	Lo Cro 46					Air cooled from 1300° F.	95	81	24	73		175			W
15	Lo Cro 46 Mo					Test at 800-1200° F.	51-80	50-65	24-18	84-66		167		Good	W
16	Lo Cro 46 W					Test at 800-1200° F.	66-103	50-90	24-18	85-68					
17	Sicromo 5					Annealed	82	95	38	76		156			F, W
18	Sivyer 5% Cr					H. T. cast	100-110	75-90	18-22	45-55		229	Good	Good	
19	Tisco 53					Cast	130-140	115-120	10-15	30-35		280-300	Good		W
20	Warman 5M					Cast	100	65	20-25	60-65			Good	Good	W

* Methods of fabrication: F, flanging; W, welding.

LOW-ALLOYED STEELS

MAKERS OF LOW-ALLOYED STEELS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Alcrosil 3	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.15 max.; Cr, 2.75-3.25; Si, 0.75-1.25; Mo, 0.5-0.65; Al, 0.5-0.6; Mn, 0.5 max.	HR, D, T
2	Bain Alloy	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.1-0.2; Cr, 1.5-2; Mo, 0.6-0.8; Mn, 0.4-0.6; Si, 0.45-0.75	T
3	Circle L 3	Lebanon Steel Fdry., Lebanon, Pa.	Fe; C, 0.45; Cr, 1; Mn, 0.7; Mo, 0.5	C
4	Circle L 5	Lebanon Steel Fdry., Lebanon, Pa.	Fe; C, 0.32; Ni, 2; Cr, 0.8; Mn, 0.72; Mo, 0.35	C
5	Circle L 19	Lebanon Steel Fdry., Lebanon, Pa.	Fe; C, 0.15; Ni, 2.5; Mn, 0.7	C
6	Copper-bearing Steel	Jones & Laughlin Steel Corp. Pittsburgh, Pa.	Fe; C, 0.15-0.30; Cu, 0.20 min; Mn, 0.4-0.8	HR, P, S, B
7	Cor-Ten	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.10 max.; Cr, 0.5-1.5; Cu, 0.3-0.5; Si, 0.5-1; Mn, 0.1-0.5	T
8	Croloy 2	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; C, 0.1; Cr, 2; Mn, 0.5; Mo, 0.5	CR, HR, T
9	Empire 12	Empire Steel Castings, Reading, Pa.	Fe; C, 0.25-0.30; Ni, 2-3; Cr, 1-1.5; Mn, 0.6-0.8; Mo, 0.25-0.35	C

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
10	Empire 14	Empire Steel Castings, Reading, Pa.	Fe; C, 0.30–0.35; Cr, 1–1.5; Mn, 0.6–0.8; Mo, 0.25–0.30	C
11	GOHI	Newport Rolling Mill Co., Newport, Ky.	Fe; C, 0.015; Cu, 0.25; Mn, 0.035; S, 0.020	S
12	Mayari R	Bethlehem Steel Co., Bethlehem, Pa.	Fe; C, 0.12 max.; Cr, 0.2-1.0; Cu. 0.5-0.7; Mn, 0.5-1.0; Ni, 0.25-0.75	B, C, CR, HR, D, P, S, R, W
13	Pennalloy 4	Penna. Electric Steel Casting Co., Hamburg, Pa.	Fe; C, 1.5–1.75; Ni, 4–4.5; Cr, 1.5–2; Mo, 0.4–0.5	C
14	Sicromo 2½	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.15 max.; Cr, 2.25-2.75; Mn, 0.50 max.; Si, 0.5-1; Mo, 0.45-0.65	B, HR, D, T
15	Sicromo 3	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.15 max.; Cr, 2.75-3.25; Si, 1-1.4; Mn, 0.50 max.; Mo, 0.45-0.65	B, HR, D, T
16	Silmo	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.15 max.; Si, 1.15–1.65; Mn, 0.50 max.; Mo, 0.45–0.65	B, HR, D, T
17	Spang Chalfant 1	Spang Chalfant Div., National Supply Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 1.75–2.25; Mn, 0.3–0.6; Mo, 0.45–0.65;	HR, T
18	Spang Chalfant 2	Spang Chalfant Div., National Supply Co., Pittsburgh, Pa.	Fe; C, 0.1–0.2; Mn, 0.3–0.6; Si, 0.25 max.	HR
19	Spang Chalfant 3	Spang Chalfant Div., National Supply Co., Pittsburgh, Pa.	Fe; C, 0.1–0.2; Mo, 0.45–0.65; Mn, 0.3–0.6; Si, 0.25 max.	HR
20	Timken Carbon-Mo	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.1–0.2; Mo, 0.45–0.65; Mn, 0.3–0.6; Si, 0.25 max.	B, HR, D, T
21	Timken 2Cr-½ Mo	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.15 max.; Cr, 1.75–2.25; Mo, 0.45–0.65; Mn, 0.3–0.6	B, HR, D, T
22	Timken DM	Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio	Fe; C, 0.15 max.; Cr, 1–1.5; Si, 0.5–1; Mo, 0.45–0.65; Mn, 0.3–0.6	B, HR, D, T
23	Tisco 41	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; C, 0.5; Cr, 1; Mn, 0.7	C
24	Tisco 80	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; C, 0.45; Ni, 2; Cr, 1.5; Mn, 0.7; Mo, 0.35	C
25	U. S. S. 1¼ Cr, ½ Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 1–1.5; Mo, 0.45–0.65; Si, 0.5–1; Mn, 0.3–0.6	T
26	U. S. S. 2 Cr, ½ Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 1.75–2.25; Mo, 0.45–0.65; Si, 0.50 max.	T
27	U. S. S. 2 Cr, ½ Mo, 1¼ Si	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 1.75–2.25; Mo, 0.45–0.65; Si, 1–1.4	T
28	U. S. S. 2½ Cr, ½ Mo, ¾ Si	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 2.25–2.75; Mo, 0.45–0.65; Si, 0.5–1	T
29	U. S. S. 2¼ Cr, 1 Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 2–2.5; Mo, 0.9–1.1; Mn, 0.50 max.	T
30	U. S. S. 3 Cr, 1 Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 2.75–3.25; Mo, 0.8–1; Si, 0.50 max.	T
31	U. S. S. 3 Cr, ½ Mo, 1¼ Si	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Cr, 2.75–3.25; Mo, 0.45–0.65; Si, 1–1.4	T
32	U. S. S. Low C, ½ Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.1–0.2; Mo, 0.45–0.65; Si, 0.25 max.; Mn, 0.3–0.6	T
33	U. S. S. Low C, 1 Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.1–0.2; Mo, 0.9–1.1; Si, 0.1–0.2; Mn, 0.3–0.6	T
34	U. S. S. 2½ Nickel	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15; Ni, 2.5; Mn, 0.3–0.6; P, 0.4 max.; S, 0.05	T
35	U. S. S. SAE 2315	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15; Ni, 3.25–3.75; Mn, 0.3–0.6	T
36	U. S. S. 1½ Si, ½ Mo	National Tube Co., Pittsburgh, Pa.	Fe; C, 0.15 max.; Mo, 0.45–0.65; Si, 1.15–1.65; Mn, 0.50 max.	T
37	Yoloy	Youngstown Sheet & Tube Co., Youngstown, Ohio	Fe; C, 0.06–0.25; Ni, 2.0 max.; Cu, 1.0 max.; Mn, 0.4–1	B, CR, HR, D, P, S, R, T, W

PHYSICAL PROPERTIES OF LOW-ALLOYED STEELS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32-212° F. (Multiply by 10⁶)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10⁶)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Alcrosil 3					Annealed	70	40	42			156			
2	Bain Alloy					Annealed tube	65 min.	40 min.	35 min.			165 max.	Fair	Fair	F, W
3	Circle L 3					Air quenched & drawn	125	90	12	20		250–300	Good	Good	
4	Circle L 5					Oil quenched & drawn	150	110	15	30		300	Variable	Good	
5	Circle L 19					Air quenched & drawn	70	40	25	40					
6	Copper-bearing Steel	7.86	2710–2750	1.04	0.115	Plate	60–72	30–36	22	40	29	131	Fair	No	R, W
7	Cor-Ten						65 min.	40 min.	45 min.		29	163 max.	Fair	Fair	F, W
8	Croloy 2			0.74		Annealed tube	60 min.	25 min.	30 min.			163 max.			F, W
9	Empire 12					Annealed casting	105	65	15–20	30–35		250	Fair	Good	W
10	Empire 14					Annealed casting	105	60	20–25	25–30		225	Fair	Good	W
11	GOHI	7.86	2795	0.66	0.17	Hot rolled	44	26	43	76	29.5	90	Fair		DD, F, R, W
12	Mayari R					Rolled	70 min.	50 min.	25	50	30	150	Good	Fair	F, R, W, B
13	Pennalloy 4											600–650	Poor	Good	
14	Sicromo 2½					Annealed	74	40	38	72		143			F, W
15	Sicromo 3			0.59		Annealed	84	45	35			150			F, W
16	Silmo			0.64		Annealed	71	42	35	66		146			F, W
17	Spang Chalfant 1			0.63		Annealed	66.4	40.6	36.5–40.3	74.1	30	131	Good	Fair	F, W
18	Spang Chalfant 2			0.61		Hot finished	62.4	42	36	67.5	30	126	Good	Fair	F, W
19	Spang Chalfant 3			0.60		Normalized & drawn	64.1	32.5	37	62.5	30	126	Good	Fair	F, W
20	Timken Carbon-Mo					Annealed	64	32.5	37	62		126			F, W
21	Timken 2Cr-½ Mo					Annealed	65	40	40	74		131			F, W
22	Timken DM			0.59		Annealed	66	35	36	72		123			F, W
23	Tisco 41					Cast	115–130	60–80	6–12	8–20		220–235			W
24	Tisco 80					Cast						300–600	Fair	Good	
25	U. S. S. 1¼ Cr, ½ Mo					Annealed tube	60 min.	40 min.	30 min.			163 max.	Fair	Fair	F, W
26	U. S. S. 2 Cr, ½ Mo					Annealed tube	60 min.	30 min.	30 min.			163 max.	Fair	Fair	F, W
27	U. S. S. 2 Cr, ½ Mo, 1¼ Si					Annealed tube	60 min.	30 min.	30 min.			163 max.	Fair	Fair	F, W
28	U. S. S. 2½ Cr, ½ Mo, ¾ Si					Annealed tube	60 min.	26 min.	30 min.			163 max.	Fair	Fair	F, W
29	U. S. S. 2¼ Cr, 1 Mo					Annealed tube	60 min.	30 min.	30 min.			163 max.	Fair	Fair	F, W
30	U. S. S. 3 Cr, 1 Mo					Annealed tube	65 min.	30 min.	30 min.			163 max.	Fair	Fair	F, W
31	U. S. S. 3 Cr, ½ Mo, 1¼ Si					Annealed tube	60 min.	30 min.	30 min.			163 max.	Fair	Fair	F, W
32	U. S. S. Low C, ½ Mo					Annealed tube	55 min.	40 min.	35 min.		29	163 max.	Fair	Fair	F, W
33	U. S. S. Low C, 1 Mo					Annealed tube	65 min.	40 min.	35 min.		29	163 max.	Fair	Fair	F, W
34	U. S. S. 2½ Nickel					Annealed tube	60 min.	40 min.	40 min.		29	124 min.	Fair	Fair	F, W
35	U. S. S. SAE 2315					Annealed tube	65 min.	40 min.	35 min.		29	130 min.	Fair	Fair	F, W
36	U. S. S. 1½ Si, ½ Mo					Annealed tube	47 min.	26 min.	35 min.			163 max.	Fair	Fair	F, W
37	Yoloy	7.87		0.65	0.08–0.1	Hot rolled	65–95	46–76	19–28		30	130–200	Good	Good	DD, F, R, W,

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

LOW-CARBON STAINLESS STEELS

MAKERS OF 11 TO 16 CHROMIUM, LOW-CARBON STEELS

No.	MATERIAL Type No. in ( )	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	**Allegheny 12** (410)	Allegheny-Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 10-13.5; C, 0.12 max.	B, C, CR, HR, D, P, S, R, T, W
2	**Allegheny 12-EZ** (410)	Allegheny-Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 12-14; C, 0.12 max.; Mn, 0.6 max.; Ni, 0.5 max.; S, 0.4 max., Mo, 0.6 (optional)	B, C, CR, HR, D, R, W
3	**Armco 13** (410)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 10-13.5; C, 0.12 max.; Mn, 0.45; Si, 0.45	P, S
4	**Avesta 393**	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 14.0; C, 0.08	HR, CR, D, P, S, T, W, B
5	**Avesta 393-S**	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 14.5; C, 0.08 max; Mo, 1.0	HR, CR, D, P, S, T, W, B
6	**Bethadur 410** (416)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 12.5; C, 0.10; Mn, 0.30; Ni, 0.20	B, HR, D, P
7	**Bethalon 416** (416)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 13; C, 0.10; Mn, 0.30; Ni, 0.25; S, 0.3-0.5	B, HR, D
8	**Carpenter Stainless 1** (410)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 12.5; C, 0.10	B, CR, HR, D, R, T, W
9	**Carpenter Stainless 5** (416)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 14; C, 0.10; S, 0.30	B, CR, HR, D, R, W
10	**Circle L 12**	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 12.5; C, 0.12	C
11	**Croloy 12**	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 12-14; C, 0.1	CR, HR, T
12	**Defirust** (410)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 10-13.5; C, 0.12 max.; Mn, 0.25-0.60; Ni, 0.50 max.; Si, 0.50 max.	B, CR, HR, D, R, W
13	**Defirust (machining)** (416)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 12-14; C, 0.12 max.; Mn, 0.25-0.60; Ni, 0.50 max.; Si, 0.50 max.; S, 0.15 min.	B, CR, HR, D, R, W
14	**Duraloy C**	Duraloy Co., Scottdale, Pa.	Fe; Cr, 12-14; C, 0.10	B, C, CR, HR, D, P, S, R, T, W
15	**Durco D-12**	Duriron Co., Dayton, Ohio	Fe; Cr, 12-14; C, 0.12	C
16	**Duro-Gloss C-1** (410)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 13; C, 0.08; Mn, 0.25	B, CR, HR, D, P, S, R
17	**Enduro FC** (416)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 12-14; C, 0.12 max.; Mn, 0.5; Mo, 0.6; Si, 0.5; S, 0.2-0.4	B, C, CR, HR, D, P, S, R, T, W
18	**Enduro S-1** (410)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 10-13.5; C, 0.12 max.; Mn, 0.60; Si, 0.60	B, C, CR, HR, D, P, S, R, T, W
19	**Enduro S (turbine)** (403)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 11.5-13; C, 0.12 max.; Mn, 0.60; Si, 0.60	B, C, CR, HR, D, P, S, R, T, W
20	**Kelcaloy**	M. W. Kellogg Co., Jersey City, N. J.	Fe; Cr, 11-15; C, 0.12 max.	P
21	**Lesco L**	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 12; C, 0.10 max.; Mn, 0.40; Si, 0.50 max.	B, CR, HR, D
22	**Midvaloy 1300** (403-410)	Midvale Co., Philadelphia, Pa.	Fe; Cr, 13; C, low	B, C, HR, R
23	**Rezistal 12**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 12-15; C, 0.12 max.	
24	**Rezistal FM 2**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 12-15; C, 0.12 max.; Mo, 0.5 max.; S, 0.45 max.	
25	**Rezistal (turbine)**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 11.5-13; C, 0.12 max.	B, CR, HR, D, P, S, R, W
26	**Sivyer 66**	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 12-14; C, 0.15 max.; Mn, 0.60 max.	C
27	**Stainless 410** (410)	Alloy Metal Wire Co., Prospect Park, Pa.	Fe; Cr, 10-13.5; C, 0.12 max.	CR, R, W
28	**Stainless FMS**	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 11.5-14; C, 0.12 max.; Mn, 0.15-0.35; S, 0.25-0.35; Si, 0.02-0.4	B, HR, D
29	**Stainless I**	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 12.5-14; C, 0.12 max.; Mn, 0.25-0.4; Si, 0.2-0.4; S, 0.025 max.	B, HR, D, S, W
30	**Stainless Iron, Mix 840**	Henry Disston & Sons, Philadelphia, Pa.	Fe; Cr, 12-14; C, 0.12 max.; Mn, 0.3-0.5; Ni, 0.5 max.; Si, 0.3-0.5	B, HR, P, S
31	**Sterling Stainless FC** (416)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 14; C, 0.10; Mo, 0.4; S, 0.25	B, HR, R
32	**Sterling Stainless T** (410)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 13; C, 0.10	B, CR, HR, D, R, W
33	**Uniloy 1409** (410)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 12-14; C, 0.10 max.	B, CR, HR, D, P, S, R, W
34	**Uniloy 1409 M** (416)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 12-15; C, 0.10 max.; Mn, 1.2 max.; Mo, 0.4-0.6; S, 0.15-0.35	B, HR, D, R, W
35	**U. S. S. 12** (410)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 10-13.5; C, 0.12 max.; Mn, 0.75 max.; Ni, 0.75 max.; Si, 0.75 max.	B, CR, HR, D, P, S, R, W
36	**Warman 13**	Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 11.5-14; C, as specified	C

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF 11 TO 16 CHROMIUM, LOW-CARBON STEELS

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, ° F.	Mean Coeff. Therm. Exp., 32-212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	**Allegheny 12** (410)	7.77	2723			Annealed bar	73	40.5	37	79	28	153	Fair	Fair	DD, F, R
2	**Allegheny 12 EZ** (416)	7.77	2723			Annealed bar	70	40	31	68	28	143	Good	Fair	DD, F, R, W
3	**Armco 13** (410)	7.65	2750-2790	0.61	0.06	Annealed	65	35	30		29	135-160	Fair	Good	DD, F, R, W, B
4	**Avesta 393**	7.73		0.90	0.070	Heat treated	125	95	23	65		280			
5	**Avesta 393-S**	7.72		0.90	0.070	Heat treated	123	79	27	57		232			
6	**Bethadur 410** (410)		2700-2750	0.60	0.057	Annealed	75	45	31	68		143	Good	Fair	DD, F, R, W, B
						Hardened	150	125	18	60		300			
7	**Bethalon 416** (416)	7.76	2700-2750	0.60		Annealed	89	65	23	56		179	Good	Fair	W, B
						Hardened	150	115	12	33		300			
8	**Carpenter Stainless 1** (410)	7.78	2525-2725	0.57	0.096	Annealed	85	60	25	75	28.5	175	Fair	Good	DD, F, R, W, B
						Hardened	180	160	15	60		375			D
9	**Carpenter Stainless 5** (416)	7.78	2525-2725	0.63	0.096	Annealed	85	60	25	55	20	187	Good	Good	D, F, R
						Hardened	164	140	11	31		351			
10	**Circle L 12**			0.57		Air quenched & temp'd	85	55	22	40		170	Good	Fair	W
11	**Croloy 12**	7.75		0.61	0.059	Annealed tube	65-78	35-45	25-35			135-160	Good	Fair	DD, F, W
12	**Defirust** (410)	7.77	2750-2790	0.61	0.060	Annealed	75	40	35	70	28.5	140	Good	Good	DD, F, R, W, B
						Hardened	190	150	10	35		400			
13	**Defirust (machining)** (416)	7.77	2750-2790	0.61	0.060	Annealed	75	40	32	65	28.5	140	Good	Good	R, B
						Hardened	185	150	10	35		375			

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, ° F.	Mean Coef. Therm. Exp., 32–212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
14	**Duraloy C**					Cast	80	50	20	30			Good		DD, F, R, W, B
15	**Durco D-12**	7.6	2750	0.60	0.05	Cast, annealed	80	50	10	15		207	Fair	Good	W
						Quenched & tempered	130	100	20	30		401			
16	**Duro-Glass C-1** (401)					Annealed rod	70	40	35	73		143	Good	Good	DD, F, R, W, B
17	**Enduro FC** (416)	7.65	2700–2750	0.57		Annealed	70–85	40–50	25–35	60–65	28	145–185	Good	Good	F, R, W
						Heat treated	80–160	60–130	15–25	40–60		180–300			
18	**Enduro S-1** (410)	7.65	2700–2750	0.57		Annealed	65–85	35–45	25–35	60–65	28	135–165	Fair	Good	DD, F, R, W
						Heat treated	100–200	60–180	10–25	25–60		293–390			
19	**Enduro S (turbine)** (403)	7.65	2700–2750	0.57		Annealed	65–85	35–45	25–35	60–65	28	135–165	Fair	Good	DD, F, R, W
						Heat treated	100–200	60–180	10–25	25–60		293–390			
20	**Kolcaloy**														DD, F, R, W, B
21	**Lesco L**	7.65	2724	0.72		HR bars & forgings	78	65	25	65		170	Good	Fair	DD, F, R, W, B
22	**Midvaloy 1300** (403–410)		2724–2750		0.099	Bar	80–200	35–170	7–30	11–70	28	140–400	Good	Fair	
23	**Resistal 12**	7.75		0.59	0.096	Annealed	87	60	31	74	28–30	170	Fair		R, W
						Hardened	182	179	18	62		363			
24	**Resistal FM 2**	7.75		0.59	0.096	Annealed	85	51	28.5	60	28–30	184	Good		R, W
						Hardened	134	76	6.5	7.6		278			
25	**Resistal (turbine)**	7.75				Quenched & tempered	100	80	20	60	28–30		Good		
26	**Sivyer 66**	7.7	2600–2700	0.58		Cast, heat treated	75–150	45–125	8–25	15–50		175–325	Good	Good	
27	**Stainless 410**** (410)	7.65	2700	0.57	0.039	Annealed rod	65–85	35–45**	25–35	60–65		135–165	Fair	Fair	R, W, B
28	**Stainless FMS**					Quenched & tempered	129	117	16.5	56			Good		
29	**Stainless I**	7.76		0.606	0.050	Quenched & tempered	116	104	22	70		241	Poor		F, R, W, B
30	**Stainless Iron, Mix 840**	7.77		1.03		Quenched & tempered	164	138					Good	Poor	
31	**Sterling Stainless FC** (416)	7.75			0.046	Annealed	87	64	25	56		185	Good	Fair	
32	**Sterling Stainless T** (410)	7.77			0.046	Hardened & drawn	120	100	22.5	70	30	240	Fair	Fair	
33	**Uniloy 1409** (410)	7.75	2775	0.60	0.096	Annealed	72–85	40–50	28–38	65–75	29	140–180	Fair	Fair	DD, F, R, W
34	**Uniloy 1409 M** (416)	7.75	2775	0.58	0.096	Annealed	70–85	40–50	23–28	50–60	29	148–180	Good	Fair	F, R, W
35	**U S S 12** (410)		2750–2790	0.61	0.060	Annealed bar	65–75	35–45	30–40	60–70	28	140–190	Fair	Good	DD, F, R, W
36	**Warman 13**					Cast, heat treated	85–95	45–50	25–30	50–60			Good	Fair	

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

** Type 416 free machining alloy with same physical properties also available.

MAKERS OF CHROMIUM FERRITES

No.	MATERIAL Type No. in. ( )	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	**Allegheny 17** (430)	Allegheny-Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 14–19; C, 0.12 max.	B, C, CR, HR, D, P, S, R, T, W
2	**Armco 17** (430)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 14–18; C, 0.12 max.; Mn, 0.3–0.6; Si, 0.50 max.; P, 0.03 max.; S, 0.03 max.	P, S, strip
3	**Avesta 249**	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 17; C, 0.10 max.	HR, CR, D, P, S, T, W, B
4	**Bethador 430** (430)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 17; C, 0.10; Mn, 0.30; Ni, 0.25	B, HR, D, P
5	**Calcro 18**	Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 16–20; C, as specified	C
6	**Carpenter Stainless 6** (430)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 17; C, 0.10	B, CR, HR, D, R, T, W
7	**Croloy 18**	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 15–18; C, 0.1	CR, HR, T
8	**Duro Glass C-2** (430)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 17; C, 0.06	B, CR, HR, D, P, S, R
9	**Enduro AA** (430)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 14–18; C, 0.12 max.; Mn, 0.50; Si, 0.50	B, C, CR, HR, D, P, S, R, T, W
10	**Lesco H** (442)	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 19; C, 0.10 max.; Mn, 0.40; Si, 0.50 max.	B, CR, HR, D
11	**Lesco M** (430)	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 16.5; C, 0.10 max.; Mn, 0.40; Si, 0.50 max.	B, CR, HR, D
12	**Midvaloy 1700** (430)	Midvale Co., Philadelphia, Pa.	Fe; Cr, 17; C, 0.12	B, C, HR, R
13	**Resistal 17**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 15–18; C, 0.12 max.	
14	**Resistal 20**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 18–23; C, 0.12 max.	
15	**Rustless 17** (430)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 14–18; C, 0.12 max.; Mn, 0.25–0.60; Ni, 0.50 max.; Si, 0.50 max.	B, CR, HR, D, R, W
16	**Rustless 17-FM** (430F)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 14–18; C, 0.12 max.; Mn, 0.25–0.60; Ni, 0.50 max.; Si, 0.50 max.; S, 0.15 min.	B, CR, HR, D, R, W
17	**Stainless C-2**	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 15–18; C, 0.12 max.; Mn, 0.25–0.40; Si, 0.2–0.4; S, 0.025 max.	B, HR, D, S, W
18	**Stainless C-2F**	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 15–18; C, 0.12 max.; Mn, 0.25–0.40; Si, 0.2–0.4; S, 0.30	B, HR, D, S, W
19	**Stainless 17 Cr** (430)	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 16–18; C, 0.12 max.; Mn, 0.60 max.; Si, 0.75 max.; S, 0.03 max.	C
20	**Stainless 14-18 Cr** (430)	Alloy Metal Wire Co., Prospect Pk., Pa.	Fe; Cr, 14–18; C, 0.12 max.; Mn, 0.50 max.	CR, D, R, W
21	**Sterling Stainless M** (430)	Firth Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 17½; C, 0.12	B, CR, HR, D, R, W
22	**Superior Stainless**	Superior Steel Corp., Carnegie, Pa.	Fe; Cr, 14–18; C, 0.12 max.	CR, HR, S
23	**Tisco 131**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 18; C, 0.10 max.; Si, 2; Mn, 0.50	C
24	**Uniloy 1800** (430)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 16–18; C, 0.12 max.; Mn, 0.3–0.5	B, CR, HR, D, P, S, R, W
25	**U S S 17** (430)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh, Pa.	Fe; Cr, 14–18; C, 0.12 max.; Mn, 0.75 max.; Ni, 0.75 max.; Si, 0.75 max.	B, CR, HR, D, P, S, R, W

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF CHROMIUM FERRITES

No.	MATERIAL Type No. in ( )		Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32-212° F. (Multiply by 10⁻⁶)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10⁶)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Allegheny 17	(430)	7.77	2714			Annealed bar	84.5	68.5	26	51.3	28	187	Fair	Fair	DD, F, R, W
2	Armco 17	(430)	7.71	2710-2750	0.64	0.06	Annealed	75	45	27		29	146	Fair	Good	DD, F, R, W, B
3	Bethadur 430	(430)		2730-2760	0.59	0.06	Annealed	75	45	28	57	29	170	Fair		DD, F, R
4	Calaxo 18						Cast, heat treated	65-75	45-52	20-25	35-40			Fair	Fair	
5	Carpenter Stainless 6	(430)	7.73	2500-2700	0.65	0.07	Annealed	80	45	27	62	28	170	Fair	Fair	
6	Croloy 18		7.72	2700-2750	0.60	0.07	Annealed tube	70-85	40-60	25-30		28-30	140-185	Fair	Fair	F, W
7	Duro-Gloss C-2	(430)					Annealed	78	50	35	70		163	Good	Good	DD, F, R, W, B
8	Enduro AA	(430)	7.60	2650-2700	0.54		Annealed	75-90	45-55	20-30	40-55	29	145-185	Fair	Fair	DD, F, R, W
							Cold drawn	90-130	65-130	2-20			185-270			
9	Lesco H	(442)	7.61	2724	1.05		HR bar & forging	74	50	27.5	61		163	Fair	Fair	DD, F, R, W, B
10	Lesco M	(430)	7.63	2724	1.30		HR bar & forging	66	44	25	65		163	Good	Fair	DD, F, R, W, B
11	Midvaloy 1700	(430)		2710-2730	0.57		Bar	65-90	45-55	20-32	40-60	29	145-210	Good	Fair	
12	Rezistal 17		7.72		0.58	0.072	Annealed	75-85	45-55	30-40	50-60	28-30	150-190	Fair		DD, R
13	Rezistal 20		7.70		0.58	0.072	Annealed	75-85	45-55	30-40	50-60	28-30	150-190	Fair		DD, R
14	Rustless 17	(430)	7.71	2500-2700	0.64	0.055	Annealed	75	45	35	75	28	140	Fair	Fair	DD, F, R, W, B
							Cold drawn	100	90	10	60	28	250			
15	Rustless 17-FM	(430F)	7.71	2500-2700	0.64	0.055	Annealed	75	45	34	62	28	140	Good	Fair	R, W, B
							Cold drawn	100	90	8	58	28	250			
16	Stainless C-2						Annealed	80	50	30	50		180			DD, F, R, W, B
17	Stainless C-2 F													Good		DD, F, R, W, B
18	Stainless 17 Cr	(430)	7.6	2425-2525	0.55	0.096	Normalized	75	45	20	35	30	196	Good		
							Drawn	100	65	15	15		217			
19	Stainless 14-18 Cr	(430)	7.60	2700	0.54	0.086	Annealed	75-90	45-55	20-30	40-55		145-185	Fair	Good	F, R, B
20	Sterling Stainless M	(430)												Poor	Poor	DD, F, R, W, B
21	Superior Stainless		7.71					75-100	45-90	35-10	60-75		130-250	Good		DD
22	Tisco 131						Cast	75-100	70-90	5-12	6-15		190-210	Good	Fair	
23	Uniloy 1809	(430)	7.72	2700	0.60	0.072	Annealed	72-80	40-45	30-35	50-60	29	140-170	Fair	Fair	F, R, W
24	U S S 17	(430)		2710-2750	0.60	0.058	Annealed plate	65-75	35-45	30-40	60-70		140-190	Fair	Good	DD, F, R, W

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

CAST, INGOT and WROUGHT IRONS

MAKERS OF CAST, WROUGHT AND INGOT IRONS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Armco Ingot Iron	Amer. Rolling Mill Co., Middletown, Ohio	Fe; C, 0.012; Mn, 0.017; P, 0.005; S, 0.025; Si, Trace	C, CR, HR, D, P, S, T, W, B
2	Buflokast Gray Iron	Buffalo Fdry. & Machine Co., Buffalo N. Y.	Fe; C, 3.2-3.6; Ni, 0-2; Si, 1-2; Mn, 0.6-0.9	C
3	Genuine Wrought Iron	A. M. Byers Co., Pittsburgh, Pa.	Fe; C, 0.02; P, 0.12; Mn, 0.05; S, 0.02; Si, 0.12; slag, 2-3	B, HR, P, S, T
4	Ni-Hard	International Nickel Co., New York, N. Y.	Fe; C, 2.75-3.6; Ni, 4.4-4.6; Cr, 1.4-1.6; Si, 0.5-1.5; Mn, 0.3-0.7	C
5	Rex Z Metal	Chain Belt Co., Milwaukee, Wis.	Fe; C, 2.5; Si, 1-1.5; Cu, 1; Mn, 0.8	C

* Forms available; B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; T, tubes; W, wire.

PHYSICAL PROPERTIES OF CAST, WROUGHT AND INGOT IRONS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coef. Therm Exp., 32-212° F. (Multiply by 10⁻⁶)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10⁶)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Armco Ingot Iron	7.87	2795	0.70	0.16	Hot rolled	42-48	26-32	22-28	65-78	30	82-100	Good	Poor	DD, F, R, B, W
2	Buflokast Gray Iron		2000-2800	0.86		Bar	30-50					150-250	Good	Good	
3	Genuine Wrought Iron	7.70	2700-2750	0.67	0.144	Rolled	48 min.	28 min.	25 min.	40 min.	29	97-105 [1]	Good	Fair	F, R, W, B
4	Ni-Hard	7.40	2150-2250			Cast	30-40		0	0		575-750	Fair	Good	
5	Rex Z Metal	7.45	2400	0.66		Bar	80	56	14		26.5	180-200	Good	Good	

[1] Rockwell B55 to B60 hardness number.

* Methods of fabrication: DD, deep drawing; F, flanging; R, riviting; W, welding, B, brazing.

HIGH-CARBON STAINLESS STEELS

MAKERS OF HIGH-CARBON STAINLESS STEELS

No.	MATERIAL Type No. in ( )	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Allegheny L-12 (420)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 13; C, 0.30	B, C, HR
2	Allegheny M-17 (440)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 17; C, 0.65	B, C, CR, HR, R, W
3	Allegheny H-17 (441)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 17; C, 1.10; Mo, 0.5; Mn, 0.05	B, C, R, W
4	Avesta 249H	A. Johnson & Co., New York, N. Y.	Fe; Cr, 17; C, 0.20–0.25	C, HR, CR, D, P, S, W, B
5	Avesta 739	A. Johnson & Co., New York, N. Y.	Fe; Cr, 13.5; C, 0.20–0.25	C, HR, CR, D, P, S, W, B
6	Avesta 739H	A. Johnson & Co., New York, N. Y.	Fe; Cr, 13.5; C, 0.35	HR, CR, D, P, S, W, B
7	Avesta 739S	A. Johnson & Co., New York, N. Y.	Fe; Cr, 14.5; C, 0.15; Mo, 1.0	C, HR, CR, D, P, S, W, B
8	B & W 900	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 17–19; C, 0.25 max.	C
9	Bethlehem 420 (420)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 14; C, 0.35; Mn, 0.30; Ni, 0.25	B, HR, D
10	Bethadur 440 (440)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 17; C, 0.65; Mn, 0.30; Ni, 0.25	B, CR
11	Carpenter Stainless 2 (420)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 13; C, 0.30	B, CR, HR, D, R, W
12	Carpenter Stainless 2-B (440)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 17; C, 1.00	B, HR, D, R
13	Carpenter Stainless 3 (442)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 20; C, 0.3; Cu, 1.0	B, CR, HR, D, R, T, W
14	Circle L 11	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 18; C, 0.25	C
15	Circle L 13	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 12.5; C, 0.25	C
16	Cooper 14	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 12–14; C, 0.10–0.25; Mn, 0.5; Cu, 1 (optional)	C
17	Cooper 16	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 16–20; C, 0.10–0.25; Mn, 0.5; Cu, 1 (optional)	C
18	Crocar	Vanadium Alloy Steel Co., Pittsburgh, Pa.	Fe; Cr, 12; C, 2.2; V, 0.8; Co, 0.5; Si, 0.3; Mn, 0.2	B, HR, D, S, W
19	Cro Sil	Crucible Steel Co., New York, N. Y.	Fe; Cr, 10–14; C, 0.20 max; Si, 3	
20	Duraloy B	Duraloy Co., Scottdale, Pa.	Fe; Cr, 16–18; C, 0.20; Mn, 0.50	B, C, CR, HR, D, P, S, R, T, W
21	Duraloy H-2	Duraloy Co., Scottdale, Pa.	Fe; Cr, 15; C, 1.0	C
22	Duron D-12 SP	Duriron Co., Dayton, Ohio	Fe; Cr, 12–14; C, 0.35	C
23	Duron D-18	Duriron Co., Dayton, Ohio	Fe; Cr, 17–21; C, 0.20	C
24	Duron D-181	Duriron Co., Dayton, Ohio	Fe; Cr, 18; C, 1.0	C
25	Duro-Gloss C-3 (442)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 20; C, 0.20; Mn, 0.25	B, CR, HR, D, P, S, R
26	Empire 46	Empire Steel Castings, Reading, Pa.	Fe; Cr, 12–14; C, 0.25 max.; Mn, 0.4–0.5	C
27	Fahrite N-9	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 12–14; C, 0.15 max.; Ni, 1.0 max.	C
28	Fahrite N-17	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 16–20; C, 0.20; Ni, 2 max.	C
29	Genesee 212	Symington-Gould Corp., Rochester, N. Y.	Fe; Cr, 14; C, 0.15; Mn, 0.50; Mo, 0.20	C
30	Lesco Stainless (420)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 13.5; C, 0.35; Mn, 0.35; Si, 0.50 max.	B, CR, HR, D
31	Lesco Hygio (440)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 17; C, 0.62; Mn, 0.35; Si, 0.50 max.	B, CR, HR, D
32	Lusterite Stainless (440)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 18; C, 0.55	B, CR, HR, D, R
33	Miscrome 1	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 16; C, 0.25 max.; Mn, 0.75; Ni, 0.80 max.	C
34	Otisel 12	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 12–14; C, 0.10–0.15; Mn, 0.50 max.	
35	Otisel 16	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 14–18; C, 0.12–0.20; Mn, 0.50 max.	
36	Pennalloy 7	Pa. Elec. Steel Casting Co., Hamburg, Pa.	Fe; Cr, 10–12; C, 1.25–1.75, Mo, 0.3–0.5	C
37	Rezistal A (420)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 12–15; C, 0.3–0.4	
38	Rezistal B (440)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 15–18; C, 0.5–0.7	
39	Rezistal Stainless BM	Crucible Steel Co., New York, N. Y.	Fe; Cr, 16–20; C, 1.0 max.; Mo, 0.5	
40	Rustless 13HC-35 (420)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 12–14; C, 0.40 max.; Mn, 0.25–0.6; Ni, 0.50 max.	B, CR, HR, D, R, W
41	Rustless 17HC-60-90 (440)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 14–18; C, 0.6–1.0; Mn, 0.25–0.6; Ni, 0.5 max.	B, CR, HR, D, R, W
42	Sta-Gloss A (420)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 13; C, 0.35; Mn, 0.35	B, P, S
43	Stainless 410 (410)	Alloy Metal Wire Co., Prospect Pk., Pa.	Fe; Cr, 10–13.5; C, 0.35	CR, R W
44	Stainless 795	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 17–17.5; C, 0.9–1.0; Ni, 0.6–1.0; Mn, 0.25–0.4	B, HR, D, S, W
45	Stainless A	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 13–14; C, 0.3–0.4; Mn, 0.25–0.4; Si, 0.2–0.4	B, HR, D, S, W
46	Stainless A Mix 830A	Henry Disston & Sons, Philadelphia, Pa.	Fe; Cr, 13–14; C, 0.25–0.35; Mn, 0.2–0.4; Si, 0.25–0.35	B, HR, P, S
47	Stainless B	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 16–17; C, 0.6–0.7; Mn, 0.25–0.4; Si, 0.2–0.4	B, HR, D, S, W
48	Stainless B Mix 831B	Henry Disston & Sons, Philadelphia, Pa.	Fe; Cr, 16–17; C, 0.5–0.6; Mn, 0.2–0.4; Si, 0.25–0.35	B, HR, P, S
49	Sterling Stainless A (420)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 13.5; C, 0.35	B, HR, D, R, W
50	Sterling Stainless B (440)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 16.5; C, 0.70	B, HR, D, R, W
51	Sterling Stainless BHH (440)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18; C, 1.05	B, HR, D, R, W
52	Sterling Stainless MG (442)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 20; C, 0.25	B, CR, HR, D, R, W
53	Uniloy 1435 (420)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 12–14; C, 0.30–0.37; Mn, 0.3–0.5	B, CR, HR, D, P, S, R, W

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF HIGH-CARBON STAINLESS STEELS

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32–212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Allegheny L-12 (420)	7.73	2700			Annealed bar	90	40	25	40	30	195	Poor	Fair	
2	Allegheny M-17 (440)	7.74	2700			Annealed bar	90	40	20–25	40–50	30	195–220	Poor	Poor	F, R
3	Allegheny H-17 (441)	7.74	2700		0.07	Tempered	158	138	6.3	11.9	30	340	Poor	Poor	
4	Avesta 249 H	7.69		0.92	0.06	Heat treated	110	90	25	50		240			
5	Avesta 739	7.73		0.90	0.07	Heat treated	231	154	16	49		460			
6	Avesta 739 H	7.73		1.05		Heat treated	165	125	14	38		300			

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32–212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
7	Avesta 739 S	7.72		0.91	0.07	Heat treated	216	141	18	51		423			
8	B & W 900	7.60		0.61		Annealed	80–90	60–70	10–20	30		160–175	Good		
9	Bethlehem 420 (420)		2580–2640	0.57	0.05	Annealed	105	55	23	55	29.5	207	Fair	Good	W, B
						Tempered	225	185	8	20		430			
10	Bethadur 440 (440)		2700–2750	0.57		Annealed	100	60	23	40		197			
						Tempered	250	190	3	6		495			
11	Carpenter Stainless 2 (420)	7.75	2500–2700	0.59		Hardened	260	225	11	32	28.5	512	Fair	Good	DD, F, R, W, B
12	Carpenter Stainless 2-B (440)	7.73	2500–2700	0.60		Hardened	286	240	1.5	14		602	Poor	Good	F, R, W, B
13	Carpenter Stainless 3 (442)	7.69	2500–2700	0.55		Annealed	100	50	22	55	28	190	Good	Fair	DD, F, R, W, B
14	Circle L11					Tempered	100	75	7.5	8.5		200	Fair	Good	W
15	Circle L13					Tempered	200	150	5	10		500 max.	Good	Good	
16	Cooper 14	7.80	2700	0.60	0.096	Cast	75	50	20	30	28	150–450	Good	Fair	
17	Cooper 16	7.60	2700	0.55	0.063	Cast	75	50	20	30	28	200	Good	Fair	
18	Crocar					Annealed	103	51		14		212	Fair	Good	F, R, W, B
19	Cro Sil														
20	Duraloy B					As cast	90	65	5	5			Good	Fair	DD, F, R, W
21	Duraloy H-2												Fair	Good	
22	Durco D-12 SP	7.6	2750	0.60	0.05	Sand cast	130	110	5–10	5–10		250–500	Fair	Good	W
23	Durco D-18	7.6	2700			Sand cast	90	55	5	5		180	Fair	Fair	W
24	Durco D-181					Sand cast	110–150	110–150	0	0		300–600	Poor	Good	W
25	Duro-Gloss C- 3 (442)					Annealed	80	55	35	55		171	Fair	Good	DD, F, R, W, B
26	Empire 46					Annealed casting	95	55	20–25	45–50		225	Fair	Fair	W
27	Fahrite N-9	7.75		0.66		Tempered	120	100	17	60		269	Good	Fair	
28	Fahrite N-17	7.7		0.65		Annealed	80	45	30	55		165	Good	Good	
29	Genesee 212	7.77					100	80	25	50		200	Good	Good	
30	Lesco Stainless (420)	7.75	2724	1.09		Rolled bar and forging	90	48	28	60		179	Good	Good	DD, F, R, W, B
31	Lesco Hygle (440)	7.70	2724	1.09		Rolled bar and forging	100	70	20	50		187	Good	Good	DD, F, R, W, B
32	Lusterite Stainless (440)	7.70	2724	1.09		Rolled bar and forging	105	75	15	40		228	Good	Good	DD, F, R, W, B
33	Miscrome 1					Cast	90	60	17	20	30	225	Good	Yes	R, W
34	Otisel 12		2723	1.04	0.064	Annealed, heat treated	70–100	40–60	10–30	40–60		140–330	Good	Good	
35	Otisel 16	7.7	2714	0.95	0.057	Annealed	75–80	45–53	20–25	30–35		145–170	Good	Poor	R, W
36	Pennalloy 7											550–600	Poor	Good	
37	Rezistal A (420)					Draw 500° F.	250	220	4	6		524			
						Draw 1400° F.	132	103	16	47		290			
38	Rezistal B (440)					Draw 200° F.						600			
						Draw 1000° F.						430			
39	Rezistal Stainless BM											R'K'w'l C 33–60		Good	
40	Rustless 13 HC-35 (420)	7.77	2550–2650	0.64	0.058	Annealed	85	40	34	68	29	160	Fair	Good	W
						Hardened	250	190	3	5		550			
41	Rustless 17 HC-60-90 (440)	7.72	2500–2700	0.64	0.058	Annealed	100	60	27	55	29	190	Fair	Good	W
						Hardened	285	275	1.5	2		625			
42	Sta-Gloss A (420)					Annealed	230	220	2.5	2		500	Fair	Good	
43	Stainless 410 (410)	7.65	2700	0.57	0.16										
44	Stainless 795												Fair		
45	Stainless A	7.74		0.606	0.052	Tempered	226	195	8.7	21.2		461	Fair		F, R, W, B
46	Stainless A Mix 830 A	7.72				Tempered	263	166	6			465	Fair	Poor	
47	Stainless B	7.74				Tempered	252	222	2	3.5		530	Good		
48	Stainless B Mix 831 B	7.72		1.15	0.058	Tempered	260	230	6			570	Poor	Poor	
49	Sterling Stainless A (420)				0.033	Heat treated	240	200	4	8	30	500	Fair	Fair	
50	Sterling Stainless B (440)	7.73				Hardened and drawn	270	245	2	3.5	30	545	Fair	Fair	
51	Sterling Stainless BHH (440)	7.73				Hardened						600	Fair	Good	
52	Sterling Stainless MG (442)												Poor	Poor	
53	Uniloy 1435 (420)	7.75	2750	0.60	0.058	Annealed	90–95	60–65	25–30	50–60	29	170–190	Fair	Fair	R, W

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

PROPERTIES OF HIGH-CHROMIUM STEELS AT HIGH TEMPERATURES

Composition Per Cent						Scaling	Strength at Elevated Temps., Lb./sq. in.			Creep Strength, Lb./sq. in. 10,000 hr. with 1% Elong.		
Cr	Ni	Mo	Si	Cb	C	Temp., °F.	1,300° F.	1,500° F.	1,700° F.	1,000° F.	1,300° F.	1,500° F.
14–16	.....	.....	.....	.....	.12	1,300	15,000	8,000	8,000	10,000	1,400	.....
16–18	.....	.....	.....	.....	.12	1,500	15,000	8,000	5,000	8,500	1,400	.....
23–30	.....	.....	.....	.....	.25	1,900	20,000	10,000	6,000	.....	800	.....
18	8	.....	.....	.....	.....	1,600	42,000	28,000	18,000	17,000	4,000	850
18	8	.....	.....	1.0[1]	.10	1,600	56,000	32,000	18,000	18,000	4,500	850
18	8	3	.....	.....	.12	1,650	60,000	40,000	18,000	25,000	10,000	3,000
18	8	.....	3	.....	.12	1,700	60,000	32,000	24,000	.....	.....	.....
25	12	.....	2	.....	.20	2,000	54,000	32,000	16,000	17,000	4,800	850
25	20	.....	2	.....	.25	2,000	45,000	28,000	14,000	17,000	5,200	1,000

[1] Or 0.60% Ti.

18-8 CHROME-NICKEL ALLOYS

MAKERS OF 18-8 CHROMIUM-NICKEL ALLOYS

No.	MATERIAL Type No. in ( )		MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Allegheny 18-8	(302)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.20 max.; Mn, 0.50 max.; Cu, 0.50 max.	B, C, CR, HR, D, P, S, R, T, W
2	Allegheny 18-8 EZ	(303)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.20 max.; Mn, 1.2 max.; Se, 0.25 (optional).	B, C, CR, HR, D
3	Allegheny 18-8-S	(304)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08 max; Mn, 0.50 max.; Cu, 0.50 max.	B, C, CR, HR, D, P, S, R, T, W
4	Allegheny 19-9	(305)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 18–20; Ni, 9–10; C, 0.20 max.	B, C, CR, HR, D, P, S, R, W
5	Allegheny 19-9 S	(306)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 18–20; Ni, 9–10; C, 0.08 max.	B, C, CR, HR, D, P, S, R, T, W
6	Allegheny 20-10	(307)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 20–22; Ni; 10–12; C, 0.20 max.	B, C, CR, HR, D, P, S, R, W
7	Allegheny 20-10-S	(308)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 20–22; Ni, 10–12; C, 0.08 max.	B, C, CR, HR, D, P, S, R, T, W
8	Allegheny 25-12	(309)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 22–26; Ni, 12–14; C, 0.20 max.; Mn, 1.25 max.	B, C, CR, HR, D, P, S, R, W
9	Allegheny 18-8-M	(316)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 16–18; Ni, 14 max.; C, 0.08; Mn, 1.75 max.; Mo, 2–3	B, C, CR, HR, D, P, S, R, W
10	Allegheny 18-8-M Spec.	(317)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 18–20; Ni, 14 max.; C, 0.08; Mn, 1.75 max.; Mo, 3–4	B, C, CR, HR, D, P, S, R, W
11	Allegheny 18-8 Cb	(347)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 17–20; Ni, 8–12; C, 0.10 max., Mn, 1.75 max., Cb, 10 ×C	B, C, CR, HR, D, P, S, R, T, W
12	Amsco F-8		Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 20–22; Ni, 8–10; C, 0.20 max; Mn, 1.0 max.; Si, 1.50 max.	C
13	Amsco F-10		Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 26-28; Ni, 10-12;C, 0.35max.;Mn, 1.0 max.; Si,1.50 max.	C
14	Armco 17-7	(301x)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 16–17.5; Ni, 7–8.5; C, 0.10–0.20; Mn, 0.65; Si, 0.45	P, S, strip
15	Armco 18-8	(302)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.12 max.; Mn, 0.3–0.6; 0.3–0.6	P, S, strip
16	Armco 18-8	(304)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08 max.; Mn, 0.3–0.6; Si, 0.3–0.6	P, S, strip
17	Armco 19-9	(305)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 18–20; Ni, 9–10; C, 0.12 max.; Mn, 0.3–0.6; Si, 0.3–0.6	P, S, strip
18	Armco 19-9	(306)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 18–20; Ni, 9–10; C, 0.08 max.; Mn, 0.3–0.6; Si, 0.3–0.6	P, S, strip
19	Armco 25-12	(309)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 22–26; Ni, 12–14; C, 0.20 max.; Mn, 1.25; Si, 0.9	P, S
20	Armco 18-12 S Mo	(316)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 16–18; Ni, 14.0 max.; C, 0.10 max.; Mn, 1.50 max.; Mo, 2-3	P, S, strip
21	Armco 18-10 Cb	(347)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 17–20; Ni, 8–12; C, 0.10 max.; Mn, 1.5 max.; Cb, min. 10 × C.	P, S, strip
22	B & W 600		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7.5–10.5; C, 0.16 max	C
23	B & W 602		Babcock & Wilcox Co., New York, N. Y	Fe; Cr, 17–19; Ni, 7.5–10.5; C, 0.07 max.	C
24	B & W 640		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 19–22; Ni, 8.5–10.5; C, 0.16 max.; Mo, 2.5–3.5	C
25	B & W 642		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 19–22; Ni, 8.5–10.5; C, 0.07 max.; Mo, 2.5–3.5	C
26	B & W 650		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 22–25; Ni, 10–13; C, 0.16 max.; Si, 0.75 max.	C
27	B & W 661		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 22–25; Ni, 10–13; C, 0.3–0.6; Si, 2.0–2.5	C
28	B & W 1500		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 26–28.5; Ni, 7.5–12; C, 0.35 max.	C
29	Bethadur 302	(302)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 18; Ni, 8; C, 0.10; Mn, 0.30	B, HR, D, P
30	Bethalon 303	(303)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 18; Ni, 8; C, 0.10; Mn, 0.30; S, 0.3–0.5 or Se, 0.15 min.	B, HR, D
31	Calite B-28		Calorizing Co., Wilkinsburg, Pa.	Fe; Cr, 26; Ni, 11; C, 0.43 max.; Mo, 1.0	C
32	Calmar 18-8		Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 17–20; Ni, 7–10; C, as specified	C
33	Calmar 18-8 Cb		Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 17–20; Ni, 7–10; C, as specified; Cb, 0.9–1.25	C
34	Calmar 18-8 M		Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 17–20; Ni, 7–10; C, as specified; Mo, 2.5–4	C
35	Caloxo 25-12		Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 24–27; Ni, 12–14; C, as specified	C
36	Caloxo 28-10		Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 27–30; Ni, 8–12; C, as specified	C
37	Carpenter Stainless 4	(302)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 18; Ni, 9; C, 0.20 max. (as specified)	B, CR, HR, D, R, T, W
38	Carpenter Stainless 8	(303)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 18; Ni, 9; C, 0.10; Se, 0.25; P, 0.13	B, CR, HR, D, R, W
39	Carpenter Stainless 4-Mo	(316)	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 16–20; Ni, 9–14; C, 0.10 max.; Mo, 2–4	B, CR, HR, D, R, T, W
40	Cimet		Driver-Harris Co., Harrison, N. J.	Fe; Cr, 23–28; Ni, 10–13	C
41	Circle L 22		Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 18; Ni, 8; C, 0.07 max.	C
42	Circle L 23		Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 18; Ni, 8; C, 0.20 max.	C
43	Circle L 30		Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 24; Ni, 11; C, 0.20	C
44	Circle L 31		Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 28; Ni, 11; C, 0.30	C
45	Cooper 17		Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 18–20; Ni, 8–10; C, 0.07–0.20; Se, 0.25 (optional)	C
46	Cooper 17 Mo		Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 18–20; Ni, 8–10; C, 0.07–0.20; Mo, 2–4; Mn, 0.50	C
47	Cooper 22		Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 25–30; Ni, 8–12; C, 0.2–0.5; Mn, 0.50	C
48	Crane 18-8		Crane Co., Chicago, Ill.	Fe; Cr, 19; Ni, 9; C, 0.12 max.	C
49	Crane 18-8 Mo		Crane Co., Chicago, Ill.	Fe; Cr, 19; Ni, 9; C, 0.12 max.; Mo, 2–4	C
50	Croloy 16-13-3		Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 15.5–17;Ni, 12.5–14.5; C 0.1; Mo, 2.5–3.25;Mn, 1.5 max.	CR, HR, T
51	Croloy 18-8		Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 17–19; Ni, 8–10.5; C, 0.1	CR, HR, T
52	Cyclops 17A	(325)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 19.75–20.75; Ni, 7–8.5; C, 0.37–0.45; Mn, 0.5–0.75	B, CR, HR, D, P, S, R, W
53	Defistain	(302)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08–0.20	B, CR, HR, D, R, W
54	Defistain Machining	(303)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.20 max.; S, 0.15 min.	B, CR, HR, D, R, W
55	Defistain	(304)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08 max.	B, CR, HR, D, R, W
56	Defistain Special	(305)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 18–20; Ni, 9–10; C, 0.08–0.20	B, CR, HR, D, R, W
57	Defistain Special	(306)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 18–20; Ni, 9–10; C, 0.08 max.	B, CR, HR, D, R, W
58	Defistain 3 Mo	(316)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 16–18; Ni, 14 max.; C, 0.10 max.; Mo, 2–3; Mn, 1–1.75	B, CR, HR, D, R, W
59	Defistain Cb	(347)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 17–20;Ni, 8–12; C, 0.10 max.; Mn, 0.25–0.75; Cb, 10 × C	B, CR, HR, D, R, W
60	Defistain Special 3 Mo		Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 18–20; Ni, 14 max; C, 0.10 max.; Mo, 3–4; Mn, 1–1.75	B, CR, HR, D, R, W
61	Duraloy 18-8		Duraloy Co., Scottdale, Pa.	Fe; Cr, 18; Ni, 8	B, C, CR, HR, D, P, S, R, T, W
62	Duraloy N		Duraloy Co. Scottdale, Pa	Fe; Cr, 24; Ni, 12; C, as specified; Mn, 0.50	B, C, CR, HR, P, S, R, T, W
63	Durco KA2S		Duriron Co., Dayton, Ohio	Fe; Cr, 18–20; Ni, 8–10; C, 0.07 max.	C
64	Durco KA2S Cb		Duriron Co., Dayton, Ohio	Fe; Cr, 18–20; Ni, 8–10; C, 0.07 max.; Cb, 10 × C	C
65	Durco KA2S FM		Duriron Co., Dayton, Ohio	Fe; Cr, 18–20; Ni, 8–10; C, 0.07 max.; Se, 0.2–0.35	C
66	Durco KA2S Mo		Duriron Co., Dayton, Ohio	Fe; Cr, 18–20; Ni, 8–10; C, 0.07 max.; Mo, 2–4	C
67	Empire 36		Empire Steel Castings, Reading, Pa.	Fe; Cr, 24–26; Ni, 11–13; C, 0.25 max.	C
68	Empire 39		Empire Steel Castings, Reading, Pa.	Fe; Cr, 17–19; Ni, 7–9; C, 0.15 max.	C
69	Enduro 18-8	(302)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08–0.20; Mn, 0.60; Si, 0.75	B, C, CR, HR, D, P, S, R, T, W
70	Enduro 18-8 B	(302B)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08–0.20; Mn, 1.5; Si, 2–3	B, C, CR, HR, D, P, S, R, T, W

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

No.	MATERIAL Type No. in ( )	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
71	Enduro 18-8 FM (303)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.20 max.; Mn, 1.5; Se, 0.07 min.; Mo, 0.6 max.	B, C, CR, HR, D, P, S, R, T, W
72	Enduro 18-8 S (304)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08 max.; Mn, 0.60; Si, 0.75	B, C, CR, HR, D, P, S, R, T, W
73	Enduro H C N (309)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 22–26; Ni, 12–14; C, 0.20 max.; Mn, 1.5	B, C, CR, HR, D, P, S, R, T, W
74	Enduro 18-8 S Mo (316)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 16–18; Ni, 14 max.; C, 0.10 max.; Mo, 2–3; Mn, 1.5	B, C, CR, HR, D, P, S, R, T, W
75	Enduro 19-9 S Mo (317)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 18–20; Ni, 14 max.; C, 0.10 max.; Mo, 3–4; Mn, 1.5	B, C, CR, HR, D, P, S, R, T, W
76	Enduro 19-9 S Ti (321)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 17–20; Ni, 7–10; C, 0.10 max.; Mn, 1.5; Ti, 4 × C	B, C, CR, HR, D, P, S, R, T, W
77	Enduro 18-8 S Cb (347)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 17–20; Ni, 8–12; C, 0.10 max.; Mn, 2.0 max.; Cb, 10 × C	B, C, CR, HR, D, P, S, R, T, W
78	Esco 40	Electric Steel Fdry. Co., Portland, Ore.	Fe; Cr, 19; Ni, 9; C, 0.30 max.; Mn, 1.0	C
79	Esco 45	Electric Steel Fdry. Co., Portland, Ore.	Fe; Cr, 19; Ni, 9; C, 0.30 max; Mo, 3; Mn, 1.0.	C
80	Fahrite C-8	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 17–21; Ni, 7–9; C, 0.12 max.	C
81	Fahrite N-3	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 24–27; Ni, 10–13; C, 0.35–0.50	C, R
82	Hi-Glass (302)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 18; Ni, 8; C, 0.08; Mn, 0.50	B, CR, HR, D, P, S, R
83	Heat Resisting 5 (309)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 24; Ni, 12; C, 0.15; Mn, 1	B, CR, HR, D, P, S, R
84	Hoskins 670	Hoskins Mfg. Co., Detroit, Mich.	Fe; Cr, 24; Ni, 12; C, 0.3–0.5; Si, 2.5; Mn, 1.5	C
85	IngAclad	Ingersoll Steel & Disc Div., Borg-Warner Corp., Chicago	Fe; Cr, 18–20; Ni, 8–10; C, 0.08 max.†	HR, P, S
86	Kolcaloy	M. W. Kellogg Co., Jersey City, N. J.	Fe; Cr, 16.5 min.; Ni, 10;–14; C, 0.12 max.; Cb and Mo optional†	P
87	Lesco 18-8 (302)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 18.5; Ni, 8.5; C, 0.20 max.; Mn, 0.40; Si, 0.50 max.	B, CR, HR, D
88	Lesco 18-8 S (304)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 18.5; Ni, 8.5; C, 0.07 max.; Mn, 0.40; Si, 0.50 max.	B, CR, HR, D
89	Lesco 25-12 (309)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 25; Ni, 12; C, 0.20 max.; Mn, 0.40; Si, 0.50 max.	B, CR, HR, D
90	Michiana 48	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 28; Ni, 8	B, C, CR, HR, P, S, R
91	Michiana 49	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 17–23; Ni, 7–10 (available with Ti or Cb)	B, C, HR, P, S, R
92	Michiana 63	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 26–30; Ni, 10–12	C
93	Michiana 100	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 24–26; Ni, 11–13 (available with Ti or Cb)	B, C, HR, P, S, R
94	Midvaloy 1800 (302-304)	Midvale Co., Philadelphia, Pa.	Fe; Cr, 18; Ni, 8; C, 0.07–0.20	B, C, HR, R
95	Midvaloy 2510 (309)	Midvale Co., Philadelphia, Pa.	Fe; Cr, 25; Ni, 10	B, C, HR, R
96	Milwaukee 18-8 (305)	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 18 min.; Ni, 8 min.; C, 0.20 max.	C
97	Milwaukee 28-12	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 27–30; Ni, 11–14; C, 0.25	C
98	Milwaukee 29-9	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 27–31; Ni, 8–10; C, 0.20 max.	C
99	Milwaukee KA2S	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 18 min.; Ni, 8 min.; C, 0.07 max.	C
100	Milwaukee KA2S Mo	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 18 min.; Ni, 8 min.; Mo, 2–4; C, 0.07 max.	C
101	Misco 18-8	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 19; Ni, 9; C, 0.15; Mn, 0.50	C, HR, P, S, B
102	Misco B	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 25; Ni, 13; C, 0.25; Mn, 0.6	C, HR, P, S, B
103	Misco C	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 29; Ni, 9; C, 0.25; Mn, 0.6	C, HR, P, S, B
104	National NA-1	National Alloy Steel Div., Blaw-Knox Co., Blawnox, Pa.	Fe; Cr, 27; Ni, 11; C, 0.30; Si, 1.25; Mn, 0.8	C, T
105	National NA-4	National Alloy Steel Div., Blaw-Knox Co., Blawnox, Pa.	Fe; Cr, 20; Ni, 10; C, 0.25; Si, 1; Mn, 1	C, T
106	Nirosta	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 16.5–19.5; Ni, 7–10	HR, CR, D, P, S, T, W, B
107	Otisel 18	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 18–20; Ni, 8–10; C, 0.08–0.12; Mn, 0.5–0.6	C
108	Otisel 24	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 22–25; Ni, 10–13; C, 0.15–0.40; Mn, 0.5–0.6	C
109	Pyrasteel 18-8	Chicago Steel Fdry. Co., Chicago, Ill.	Fe; Cr, 18; Ni, 8; C, 0.20	C
110	Pyrasteel 2800	Chicago Steel Fdry. Co., Chicago, Ill.	Fe; Cr, 26; Ni, 14; C, 0.35; Mn, 0.9	C
111	Q Alloy CN1	General Alloys Co., Boston, Mass.	Fe;Cr 24–26; Ni, 11–13; C, 0.07–0.20; Mn, 0.5–1.0	B, C, S
112	Rezistal KA2 (302)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.08–0.20	
113	Rezistal 2C (302B)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.08–0.20; Si, 2–3	
114	Rezistal FM 188 (303)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 18–19; Ni, 8–0.5; C, 0.07 max.; Mo, 0.75 max.	B, CR, HR, D, P, S, R, W
115	Rezistal KA2 S (304)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 18; Ni, 8; C, 0.07	B, CR, HR, D, P, S, R, W
116	Rezistal 3 (309)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 21–26; Ni, 10–13; C, 0.20 max.	
117	Rezistal KA2S Mo (316-317)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 16–20; Ni, 7–11; C, 0.07 max., Mo, 2–4	
118	Rezistal KA2ST (321)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.07 max.; Ti, 0.35 min.	
119	Rezistal KA2 Cb (347)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–20; Ni, 8–12; C, 0.10 max.; Cb, 10 × C	B, CR, HR, D, P, S, R, W
120	Rustless 20-10 (307-308)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 20–22; Ni, 10–12; C, 0.20 max.	B, CR, HR, D, R, W
121	Rustless 25-12 (309)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 22–26; Ni, 12–14; C, 0.20 max.	B, CR, HR, D, R, W
122	Sivyer 60	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 18; Ni, 8; C, 0.12 max.; Mn, 60 max.	C
123	Sivyer 62	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 23–25; Ni, 11–13; C, 0.20 max.; Mn, 0.60 max.	C
124	Sivyer 64	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 26–28; Ni, 9–11; C, 0.20 max.; Mn, 0.60 max.	C
125	Stainless 18-8‡ (302)	Alloy Metal Wire Co., Prospect Pk., Pa.	Fe; Cr, 18; Ni, 8; C, 0.08–0.20; Mn, 0.60 max.	CR, D, R, W
126	Stainless N (302)	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 17.5–18.5; Ni, 8.5–9.5; C, 0.15 max.; Mn, 0.2–0.5	B, HR, D, S, W
127	Stainless U	Vanadium-Alloys Steel Co., Pittsburgh, Pa.	Fe; Cr, 18.5–19.5; Ni, 8.5–9.5; C, 0.15 max.; Mo, 1.25–175; Cu, 1–1.5	B, HR, D, S, W
128	Standard 25-12	Standard Alloy Co., Cleveland, Ohio	Fe; Cr, 25; Ni, 12; C, 0.40; Mn, 0.70; Si, 1.50	C
129	Sterling Nirosta KA2 (302)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18; Ni, 8.5; C, 0.15	B, CR, HR, D, R, W
130	Sterling Nirosta FC (303)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18; Ni, 8.25; C, 0.12; Se	B, HR, D, R, W
131	Sterling Nirosta KA2S (304)	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18; Ni, 8.25; C, 0.08	B, HR, D, R, W
132	Superior Stainless	Superior Steel Corp., Carnegie, Pa.	Fe; Cr, 17.5–20; Ni, 8–10; C, 0.12 max.	CR, HR, S
133	Symington Nirosta KA2	Symington-Gould Corp., Rochester, N. Y.	Fe; Cr, Ni	C
134	Thermalloy E	Electro-Alloys Co., Elyria, Ohio	Fe; Cr, 27–30; Ni, 8–10	C
135	Timken 18-8	Steel & Tube Div., Timken Roller Bearing Co., Canton, O.	Fe; Cr, 17.5–19.5; Ni, 8–10; C, 0.07 max.; Mn, 0.50 max.	B, HR, D, T
136	Tisco 18Z	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 18; Ni, 8; C, 0.07 max.; Si, 2.0 max.; Mn, 1.0 max.	C
137	Tisco 18Y	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 20; Ni, 8; C, 0.16 max.; Mo, 2–4; Si, 2 max.; Mn, 1 max.	C
138	Uniloy 18-8 (302)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08–0.20; Mn, 0.3–0.5	B, CR, HR, D, P, S, R, W
139	Uniloy 18-8 M (303)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 18–20; Ni, 8–10; C, 0.08 max.; Mn, 0.8–1.2; Se, 0.15–0.30	B, CR, HR, D, R, W
140	Uniloy 18-8 S (304)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08 max.; Mn, 0.3–0.5	B, CR, HR, D, R, W
141	Uniloy 25-12 (309)	Universal-Cyclops Steel Corp., Bridgeville, Pa.	Fe; Cr, 22–26; Ni, 12–15; C, 0.08–0.20; Mn, 1.40 max.	B, CR, HR, D, P, S, R, W
142	U. S. S. 18-8 (302)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 17.5–19; Ni, 8–9; C, 0.08–0.20; Mn, 0.75 max.	B, CR, HR, D, P, S, R, T, W

† Refers to stainless surface. (For IngAclad this comprises about 20 per cent of total sheet or plate thickness.)

‡ Types 303 and 304 also available.

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

No.	MATERIAL Type No. in ( )	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
143	U. S. S. 18-8 FM (303)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 17.5-19; Ni, 8-9; C, 0.20 max.; S or, Se, 0.07 min.	B, R, W
144	U. S. S. 18-8 S (304)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 17.5-19; Ni, 8-9; C, 0.08 max.; Mn, 0.75 max.	B, CR, HR, D, P, S, R, T, W
145	U. S. S. 19-9 S (306)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 18-20; Ni, 9-10; C, 0.08 max.; Mn, 0.75 max.	B, CR, HR, D, P, S, R, T, W
146	U. S. S. 20-10 S (308)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 20-22; Ni, 10-12; C, 0.08, max.; Mn, 0.75 max.	B, CR, HR, D, P, S, R, T, W
147	U. S. S. 25-12 (309)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 22-26; Ni, 12-14; C, 0.20 max.; Mn, 2.0 max.	B, CR, HR, D, P, S, R, W
148	U. S. S. 18-8 Mo (316)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 16-18; Ni, 14max.; C, 0.10 max.; Mo, 2-3; Mn, 2.0 max.	B, CR, HR, D, P, S, R, W
149	U. S. S. 19-9 Mo (317)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 18-20; Ni, 14 max.; C, 0.10 max.; Mn, 2.0 max.; Mo, 2-4	B, CR, HR, D, P, S, R, W
150	U S. S. 18-8 Ti (321)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 17-20; Ni, 8-11; C, 0.10 max.; Ti, 4 × C min.	B, CR. HR, D, P, S, R, T, W
151	U. S. S. 18-8 Cb (347)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 17-20; Ni, 8-12 C, 0.10 max.; Mn, 2.0 max.	B, CR, HR, D, P, S, R, T, W

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, roads; T, tubes; W, wire.

PHYSICAL PROPERTIES OF 18-8 CHROMIUM-NICKEL ALLOYS

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Allegheny 18-8 (302)	8.02	2606-2679	0.96	0.069	Annealed rolled	90	35	55-60	50-75	28.6	135-150	Poor	Poor	DD, F, R, W
2	Allegheny 18-8EZ (303)	7.90	2606-2679	0.96	0.069	H. R. annealed bars	85	39	56.5	67.5	28.6	163	Good	Fair	Machining
3	Allegheny 18-8-S (304)	8.02	2606-2679	0.96	0.069	Annealed rolled	85	30	60	60-75	28.6	135-145	Poor	Poor	DD, F, R, W
4	Allegheny 19-9 (305)	8.02	2606-2679	0.96	0.069	H. R. annealed bars	90	35	55-60	50-75	28.6	135-150	Poor	Poor	
5	Allegheny 19-9S (306)	8.02	2606-2679		0.069	Annealed rolled	85	30	60	60-75	28.6	135-145	Poor	Poor	DD, F, R, W
6	Allegheny 20-10 (307)	8.02	2606-2679	0.96	0.069	H. R. annealed bars	90	35	55-60	50-75	28.6	135-150	Poor	Poor	DD, F, R, W
7	Allegheny 20-10S (308)	8.02	2606-2679	0.96	0.069	H. R. annealed bars	90	35	55-60	50-75	28.6	135-150	Poor	Poor	DD, F, R, W
8	Allegheny 25-12 (309)	8.00	2552-2597	0.90	0.04	H. R. annealed bars	100	46	50	70	29	149	Fair	Fair	DD, F, R, W
9	Allegheny 18-8M (316)	8.06	2606-2679	0.83	0.052	H. R. annealed bars	95	40	60	65	28.6	150-200	Fair	Fair	DD, F, R
10	Allegheny 18-8M Spec. (317)	8.06	2606-2679	0.83	0.052	H. R. annealed bars	95	40	60	65	28.6	150-200	Fair	Fair	DD, F, R, W
11	Allegheny 18-8Cb (347)	7.97	2606	0.96	0.053	Annealed rolled	85	30	60	60-75	28.6	135-145	Poor	Poor	DD, F, R, W
12	Amaco F-8	7.9	2460-2600	0.90	0.06	As cast	70-90	25-45	40-70	40-70		150-180	Good	Good	W
13	Amaco F-10	8.0	2460-2570	0.80	0.035	As cast	80-100	40-55	15-35	12-32		160-190	Fair	Good	W
14	Armco 17-7 (301X)	7.90	2600	0.94	0.05	Annealed	90	45	55		29	143-170	Fair	Good	DD, F, R, W, B
15	Armco 18-8 (302)	7.93	2550-2590	0.95	0.048	Annealed	90	45	55-60		29	130-162	Fair	Good	DD, F, R, W, B
16	Armco 18-8 (304)	7.93	2550-2590	0.95	0.048	Annealed	85	40	60-65		29	125-150	Fair	Good	DD, F, R, W, B
17	Armco 19-9 (305)	7.93	2550-2590	0.95	0.048	Annealed	90	45	55-60		29	130-162	Fair	Good	DD, F, R, W, B
18	Armco 19-9 (306)	7.93	2550-2590	0.95	0.048	Annealed	85	40	60-65		29	125-150	Fair	Good	DD, F, R, W, B
19	Armco 25-12 (309)	7.88	2530-2570	0.83	0.035	Annealed	95	45	45		29	170	Fair	Good	DD, F, R, W, B
20	Armco 18-12 SMo (316)	8.03	2500-2550	0.90	0.041	Annealed	85	40	60		28	135-180	Fair	Good	DD, F, R, W, B
21	Armco 18-10 Cb (347)	8.02	2550-2600	0.90	0.038	Annealed	85	40	45-55		29	140-180	Fair	Good	DD, F, R, W, B
22	B & W 600	7.85	2600	0.88	0.035	Annealed	60-70	30-35	40-60	40-70		160-210	Fair		
23	B & W 602	7.85	2600	0.88	0.035	Annealed	60-70	30-35	40-60	40-70		160-210	Fair		
24	B & W 640	7.86		0.89		Annealed	80-90	40-45	40-55	50-70		185-210	Fair		
25	B & W 642	7.86		0.89		Annealed	80-90	40-55	40-55	50-70		185-210	Fair		
26	B & W 650	7.85	2550	0.90		Annealed	70-90	30-45	35-50	30-60		150-200	Fair		
27	B & W 661	7.85	2600	0.90		As cast	65-85	35	10-27	15-45		185-225	Fair		
28	B & W 1500	7.87	2600-2700	0.72	0.03	As cast	95	65	25	35		175-185	Fair		
29	Bethadur 302 (302)	7.90	2600-2750	0.92	0.042	Annealed	88	35	55	60		163	Fair		DD, F, R, W, B
						Cold drawn	150	130	30	55		280			
30	Bethalon 303 (303)		2600-2750	0.92	0.042	Annealed	88	35	35	50		150	Fair		W, B
31	Calite B-28	8.22	2800	1.10 [2]		Annealed casting	80 min.		9-18			210	Fair	Fair	W
32	Calmar 18-8					Annealed casting	80-90	38-45	55-65				Fair	Good	
33	Calmar 18-8 Cb					Annealed casting	80-85	40-45	40-45				Fair	Good	
34	Calmar 18-8 M					Annealed casting	85-95	40-50	25-30			150	Fair		
35	Calorz 25-12					Annealed casting	75-85	40-45	30-35						
36	Calorz 28-10					Annealed casting	70-90	40-45	30-30						
37	Carpenter Stainless 4 (302)	7.93	2500-2700	0.88	0.053	Annealed	85	35	62	70	28	150	Poor	Good	DD, F, R, W, B
38	Carpenter Stainless 8 (303)	7.86	2500-2700	0.88	0.052	Annealed	85	35	45	56	28	170	Excellent	Good	DD, F, R
39	Carpenter Stainless 4-Mo (316)	8.00	2500-2700	0.84	0.052	Annealed	85	35	60	70	28	150	Fair	Good	DD, F, R, W, B
40	Cimet														
41	Circle L22	7.8		0.89	0.063		70	32	45	50		140-175	Fair	Fair	W
42	Circle L23	7.8		0.89	0.063		72.5	32.5	40	45			Fair	Fair	W
43	Circle L30	7.85		0.85	0.030	Water quenched	80	40	30	30		160	Fair	Fair	
44	Circle L31	7.9		0.78	0.025	Water quenched	90	50	25	25			Fair	Fair	
45	Cooper 17	7.85	2650	0.89	0.06	Cast	80	40	47	50	28	150	Good	Fair	
46	Cooper 17 Mo	7.85	2650	0.89	0.06	Cast	85	43	47	50	28	160	Good	Fair	
47	Cooper 22	7.90	2675	0.90	0.035	Cast	75	45	12	18	28	160	Good	Fair	
48	Crane 18-8					Annealed casting	75	35	30	35		150-170			
49	Crane 18-8 Mo					Annealed casting	75	35	30	35		150-170			
50	Croloy 16-13-3	8.03	2550	0.90	0.05	Annealed tube	75 min.	30	40			200 max.	Fair	Fair	DD, F, W
51	Croloy 18-8	7.90	2550	0.92	0.052	Annealed tube	75 min.	30 min.	40 min.		28	200 max.	Fair	Fair	DD, F, W
52	Cyclops 17A (325)	8.0	2650	0.93	0.074	Annealed	105-125	60-85	27-50	50-65	28	170-223	Fair	Good	R, W
53	Defistain (302)	7.93	2500-2600	0.95	0.048	Annealed, cold drawn	85-250	35-200	5-60	55-70	27	140-425	Fair	Good	DD, F, R, W, B

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing. [2] 1650°F.

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. (Multiply by 10⁻⁶)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10⁶)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
54	Defistain Machining (303)	7.93	2500–2600	0.95	0.048	Annealed, cold drawn	85–225	35–150	5–55	50–65	27	140–400	Good	Fair	DD, F, R, W, B
55	Defistain (304)	7.93	2500–2600	0.95	0.048	Annealed, cold drawn	85–250	35–200	5–60	55–70	27	140–425	Fair	Good	DD, F, R, W, B
56	Defistain Special (305)	7.93	2500–2600	0.95	0.048	Annealed, cold drawn	85–250	35–200	5–60	55–70	27	140–425	Fair	Fair	DD, F, R, W, B
57	Defistain Special (306)	7.93	2500–2600	0.95	0.048	Annealed, cold drawn	85–250	35–200	5–60	55–70	27	140–425	Fair	Fair	DD, F, R, W, B
58	Defistain 3 Mo (316)	8.03	2500–2550	0.90	0.041	Annealed, cold drawn	80–225	35–200	3–60	35–60	27	140–400	Poor	Fair	DD, F, R, W, B
59	Defistain Cb (347)	7.96	2500–2600	0.95	0.048	Annealed, cold drawn	80–225	30–200	3–55	35–60	27	140–400	Fair	Fair	DD, F, R, W, B
60	Defistain Special 3 Mo (317)	8.03	2500–2550	0.90	0.041	Annealed, cold drawn	80–225	35–200	3–60	35–60	27	140–400	Poor	Fair	DD, F, R, W, B
61	Duraloy 18-8	7.86	2550			As cast	75	35	35	40			Good		DD, F, R, W
62	Duraloy N	7.86	2600	0.90		As cast	80	50	20–35	20–35			Fair	Fair	DD, F, R, W
63	Durco KA2S	7.80	2650	0.90	0.050	Sand cast	80–90	30–40	40–55	40–55		130–150	Fair	Fair	W
64	Durco KA2S Cb	7.8	2650			Sand cast	80–90	30–40	40–55	40–55		130–150	Fair	Fair	W
65	Durco KA2S FM	7.8	2650			Sand cast	70	30	40–55	40–55		130–140	Good	Fair	W
66	Durco KA2S Mo	7.84	2650	0.90	0.050	Sand cast	85–95	45–55	40–50	45–55		140–160	Fair	Fair	W
67	Empire 36					Annealed casting	75	40	35–40	40–50		175	Fair	Poor	W
68	Empire 39					Annealed casting	75	40	50–55	60–65		165	Fair	Poor	W
69	Endure 18-8 (302)	7.98	2550–2600	0.90		Annealed	80–90	35–45	55–60	55–60	28	135–185	Fair	Fair	DD, F, R, W
						Cold rolled	100-200	50–150	5–50			180–330			
70	Endure 18-8B (302B)	7.90	2500–2550	0.90			80–100	40–50	50–60	50–70	28	150–180	Fair	Fair	DD, F, R, W
71	Endure 18-8 FM (303)	7.98	2550–2600	0.90			80–90	35–45	50–60	55–70	28	130–150	Excellent	Fair	DD, F, R, W
72	Endure 18-8 S (304)	7.98	2550–2600	0.90		Annealed	80–90	35–45	55–60	55–60	28	135–185	Fair	Fair	DD, F, R, W
						Cold rolled	100-200	50–150	5–50			180–330			
73	Endure HCN (309)	7.88	2500–2550	0.80			90–110	40–60	50–65	50–65	30	140–185	Fair	Fair	DD, F, R, W
74	Endure 18-8 S Mo (316)	8.05	2500–2550	0.84			80–90	35–55	60–70	60–75	28.5	135–185	Fair	Fair	DD, F, R, W
75	Endure 19-9 S Mo (317)	8.05	2500–2550	0.84			80–90	35–55	60–70	60–75	28.5	135–185	Fair	Fair	DD, F, R, W
76	Endure 19-9 S Ti (321)	8.02	2550–2600	0.88		Annealed	80–90	35–45	55–60	55–65	28	135–185	Fair	Fair	DD, F, R, W
						Cold rolled	110-180	50–150	10–50						
77	Endure 18-8 S Cb (347)	8.02	2550–2600	0.88			80–90	35–45	55–60	55–65	28	135–185	Fair	Fair	DD, F, R, W
78	Esco 40	7.98	2550	0.90	0.052		90	50	60	55	30	150	Good	Poor	
79	Esco 45	8.05	2550	0.84	0.052		90	50	50	50	30	170	Good	Poor	
80	Fahrite C-8	7.80		0.80		Heat treated	75	30	40	40		140	Fair	Fair	
81	Fahrite N-3	7.73		1.05		As cast	90	40	20	20	24.2	172	Good	Fair	
82	Hi-Gloss (302)					Annealed	90	45	60	70		950	Fair	Good	DD, F, R, W, B
83	Heat Resisting 5 (309)					Annealed	100	45.4	60	68		163	Fair	Good	DD, F, R, W, B
84	Hoskins (670)	7.9	2400–2450	0.88	0.036	As cast	60–80	45	6–10			150–185	Good	Good	W
85	Ing Aclad	7.85	2600	0.90	0.07	Stainless layer	80–90	45–50	55–60	55–65	29	75–90	Fair	Fair	DD, F, W
					0.13	Mild steel layer	55–65	35–45	30–40	60–70	30	120–140			
86	Kelcaloy														
87	Lesco 18-8 (302)	7.88	2724	0.90	0.046	Rolled bars & forgings	87	33	58	70	28.5	143	Fair	Fair	DD, F, R, W, B
88	Lesco 18-8 S (304)	7.88	2724	0.90	0.046	Rolled bars & forgings	87	33	58	70	28.5	143	Fair	Fair	DD, F, R, W, B
89	Lesco 25-12 (309)	7.86	2724	0.90	0.040	Rolled bars & forgings	90	40	45	62		156	Fair	Fair	DD, F, R, W, B
90	Michiana 48	7.75		0.83		Cast	75	45	3	3		190	Fair		
91	Michiana 49	7.7				Cast	75	45	3	3		190	Fair		
92	Michiana 63												Fair		
93	Michiana 100	7.87		0.90		Cast	70.5	40	14.5	16.4	23.8	170	Fair		
94	Midvaloy 1808 (302-304)	7.86	2550–2990	0.91	0.039	Wrought	75–145	30–110	20–60	30–70	29	130–280	Fair	Fair	
						Cast	70–85	35–45	35–50	30–60		130–150			
95	Midvaloy 2510 (309)	7.86				Wrought	75–115	40–60	25–45	30–50		140–185	Fair	Fair	
						Cast	70–78	40–46	3.5–15	4.5–16.5		166–213			
96	Milwaukee 18-8 (305)	7.8	2552–2675	0.85	0.063	Water quenched	70–80	25–40	40–70	40–75	29	160–187	Fair		
97	Milwaukee 28-12	7.9		0.77	0.039								Poor		
98	Milwaukee 29-9	7.9	2550–2675	0.80		Softened	80–90	40–50	35–50	35–60		187–207	Fair		
99	Milwaukee KA2S	7.8	2600–2675	0.85	0.058	Softened	70–80	25–30	40–70	40–75	29	160–187	Fair		
100	Milwaukee KA2S Mo	7.9	2600–2675	0.80		Softened	80–90	40–50	35–50	45–70		178–196	Fair		
101	Misco 18-8					Cast	70	35	40	40		200	Fair	Yes	
102	Misco B					Cast	70	35	30	30	23.6	200	Fair		R,W
103	Misco C				0.76	Cast	85	45	20	20	21.9	225	Fair		R, W
104	National NA-1	7.80	2720	0.80	0.030	Annealed casting	85	55	25	27	32	160	Good	Good	W
105	National NA-4	7.86	2630	0.89	0.052	Annealed casting	80	40	45	55	30	140			W
106	Nirosta	7.86	2642	0.88	0.052	Wrought	85–90	40	55–60	65			Fair	Poor	DD, F, R, W, B
107	Otisel 18	7.85	2606–2678	0.94	0.069	Water quench 2000° F	75–85	35–40	55–65	60–70	28.8	130–140	Good	Poor	R, W
108	Otisel 24	8.01	2550	0.90	0.039	Water quench 2000° F	75–99	38–45	50–60	40–50	29	140–170	Good	Poor	R, W
109	Pyrasteel 18-8	7.8		0.89	0.063		70	32	35	40		155	Good	Fair	
110	Pyrasteel 2000	7.75			0.025		75	40	12	15		165	Fair	Fair	
111	Q Alloy CN1	8.05	2700–2800	0.89	0.024	Cast	70–90	34–50	40–50	55–65	27	207	Fair	Good	W
112	Rezistal KA2 (302)	7.94	2550	0.89	0.052	Annealed	85–95	30–40	55–60	65–75	28–30	130–170	Fair		R, W
113	Rezistal 2C (302B)	7.77		0.89		Annealed	90–100	40–50	50–60	50–70	28–30	140–180	Fair		R, W
114	Rezistal FM 188 (303)														
115	Rezistal KA2 S (304)	7.94	2550	0.89		Annealed	85–95	30–40	55–60	65–75	28–30	130–170	Good		
116	Rezistal 3 (309)			0.89	0.039	Annealed	95–105	40–50	40	50	28–30	170–200	Fair		R, W
117	Rezistal KA2 S Mo (316-317)	7.91		0.89	0.052	Annealed	90–100	40–50	50–60	60–75	28–30	170–200	Fair		R, W
118	Rezistal KA2 ST (321)	7.94	2550	0.89	0.052	Annealed	85–95	30–40	55–60	65–75	28–30	130–170	Fair		R, W

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32-212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
119	Refistal KA2 Cb (347)												Good		
120	Rustless 20-10 (307-308)	7.93	2500-2600	0.95	0.048	Annealed, cold drawn	95-225	35-175	5-60	55-70	27	140-400	Poor	Fair	R, W, B
121	Rustless 25-12 (309)	7.88	2600-2700	0.83	0.035	Annealed, cold drawn	100-225	50-150	5-45	50-60		160-400	Fair	Fair	DD, R, W, F, B
122	Sivyer 60	7.85	2600-2700	0.90		Cast, heat treated	70-80	35-45	45-55	45-60		156	Fair	Fair	
123	Sivyer 62	7.8	2600-2700	0.90		Cast	75-85	35-45	35-45	35-45		163	Fair	Fair	
124	Sivyer 64	7.8	2600-2700	0.90		Cast	85-95	40-50	20-30	20-30		197	Fair	Fair	
125	Stainless 18-8 [1] (302)	7.93	2700			Annealed	85-95	35	40	70-75	29	145-160	Poor	Good	DD, F, R, W, B
126	Stainless N (302)	7.93		1.0	0.035	Annealed	92	48	58	70		155	Fair		DD, F, R, W, B
127	Stainless U	7.96		1.0		Annealed	87	40	52	71.6		150	Fair		DD, F, R, W, B
128	Standard 25-12	7.86	2650		0.025	Cast	85	60	20	3		180-210	Fair	Good	W
129	Sterling Nirosta KA2 (302)	7.93	2700		0.039	Annealed	90	30	55	70	29	150	Poor	Fair	DD, F, R, W, B
130	Sterling Nirosta FC (303)					Annealed						185	Good		
131	Sterling Nirosta KA25 (304)											150			
132	Superior Stainless	7.93			0.048		85-250	35-200	5-60	55-70		130-350	Good		DD
133	Symington Nirosta KA2	7.93					65	35	35-40	55-65		145-160	Good		
134	Thermalloy E											170-240			
135	Timken 18-8			0.87		Water quench 2000° F.	82.5	30.5	61	74		137			F, W
136	Tisco 102					Cast	65-70	25-30	50-60	45-60			Poor	Poor	
137	Tisco 104					Cast	70-75	30-35	50-60	45-60		130-150	Poor	Poor	
138	Uniloy 18-8 (302)	7.91	2550	0.96	0.052	Annealed	95-95	30-45	55-60	60-75	28	135-185	Fair	Good	DD, F, R, W
139	Uniloy 18-8 M (303)	7.71	2700	0.96	0.052	Annealed	80-95	35-40	45-55	60-65	27	165-180	Good	Fair	R, W
140	Uniloy 18-8 S (304)	7.91	2550	0.96	0.052	Annealed	85-95	30-45	55-60	60-75	28	135-185	Fair	Good	DD, F, R, W
141	Uniloy 25-12 (309)	7.90	2600	0.83	0.039	Annealed	90-100	40-50	35-50	50-60	29	160-200	Fair	Good	F, R, W
142	U. S. S. 18-8 (302)	7.90	2550-2590	0.96	0.039	Annealed bar	80-95	35-45	55-65	60-70	29	135-185	Poor	Good	DD, F, R, W
143	U. S. S. 18-8 FM (303)	7.90	2550-2590	0.95	0.039	Annealed bar	80-90	35-45	50-60	55-65		135-210	Good	Good	
144	U. S. S. 18-8 S (304)	7.90	2550-2590	0.96	0.039	Annealed bar	80-90	30-40	55-65	60-70	29	135-185	Poor	Good	DD, F, R, W
145	U. S. S. 19-9 S (306)	7.90	2550-2590	0.96	0.039	Annealed bar	80-90	30-40	55-65	60-70	29	135-185	Poor	Good	DD, F, R, W
146	U. S. S. 20-10 S (308)	7.90	2550-2590	0.96	0.039	Annealed bar	80-90	30-40	55-65	60-70	29	135-185	Poor	Good	DD, F, R, W
147	U. S. S. 25-12 (309)	7.90	2530-2570	0.83	0.035	Annealed bar	100-110	45-55	45-55	55-65	29	145-190	Poor	Good	DD, F, R, W
148	U. S. S. 18-8 Mo (316)	8.05	2500-2550	0.84	0.038	Annealed plate	85-95	35-50	55-65	60-70		135-185	Poor	Good	DD, F, R, W
149	U. S. S. 19-9 Mo (317)	8.05	2500-2550	0.84	0.038	Annealed plate	85-95	35-50	55-65	60-70		135-185	Poor	Good	DD, F, R, W
150	U. S. S. 18-8 Ti (321)	7.90	2550-2590	0.93	0.039	Annealed plate	80-95	35-45	50-60	55-65		135-185	Poor	Good	DD, F, R, W
151	U. S. S. 18-8 Cb (347)	7.90	2550-2590	0.93	0.039	Annealed plate	80-90	35-45	50-60	55-65		135-185	Poor	Good	DD, F, R, W

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

[1] Types 303 and 304 also available.

[2] To 1650 deg. F.

HIGH-SILICON CAST IRONS

MAKERS OF HIGH-SILICON CAST IRONS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available
1	Antaciron	Antaciron, Inc., Raritan, N. J.	Fe; Si, 14.5; C, 0.60; Mn, 0.60	Castings
2	Corrosiron	Pacific Foundry Co., San Francisco, Calif.	Fe; Si, 14.25; C, 0.8-1.0; Mn, 0.50	Castings
3	Durichlor	Duriron Co., Dayton, Ohio	Fe; Si, 14.5; C, 0.8; Mo, 3	Castings
4	Duriron	Duriron Co., Dayton, Ohio	Fe; Si, 14.5; C, 0.8; Mn, 0.35	Castings
5	Tantiron	Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.	Fe; Si, 13.5; C, 0.8-1.0	Castings

PHYSICAL PROPERTIES OF HIGH-SILICON CAST IRONS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32-212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication
1	Antaciron	7.1	2350	0.7		Cast bar	16					425-475	Poor	Good	
2	Corrosiron	7.02	2400		0.13	Cast	16	0	0	0		275-325	Machinable	Good	
3	Durichlor	7.04	2350	0.36	0.125	Sand cast	17					52 [1]	Grind. only	Good	Welding
4	Duriron	7.0	2300	0.36	0.125	Sand cast	16-18					52 [1]	Grind. only	Good	Welding
5	Tantiron												Grind. only	Good	

[1] Rockwell "C" hardness number.

COMPARATIVE PRICES of STAINLESS STEELS

ONE OF THE DETERMINING FACTORS in the selection of a material from which to construct equipment for use in the chemical industries is price. When several materials are of equal suitability from all other considerations the engineer naturally chooses the one that is obtainable at the lowest cost. For the purpose of assisting in the selection, the current prices of some of the alloy steels are given in the accompanying table. While these prices may change slightly from time to time it is probable that their relation, one to another, will continue as at present.

It is essential to keep in mind that these are base prices of the steels in the form of plates, sheets, cold rolled strip, and so forth. And while the prices are comparable and therefore offer a useful guide, when selecting materials of construction other factors enter into the delivered cost of the alloy steel sheet, bar, wire, or other form. To the base price of the steel must be added extra charges that are due to such factors as quantity of the material ordered, the degree of surface finish specified and whether one or both sides are polished, width, length and thickness. It is sometimes necessary to specify other requirements that add to the cost. Among those that should be mentioned are: close tolerance, testing, packing, machining, perforation, cutting to size, and in the case of bars, shape.

While this list of extras may appear to be long the average added cost for extras rarely prohibits the use of the steel.

Standard Type Numbers and Analyses Applicable Thereto.

TYPE NO.	CARBON	CHROME	NICKEL	OTHER ELEMENTS	Bars Drawn Wire Structurals	PLATES	SHEETS	HOT ROLLED STRIP	COLD ROLLED STRIP	FORGING BILLETS
301X	.10-.20	16.00-17.50	7.00- 8.50	.....	24c	27c	34c	20½c	25½c	20.40c
302	Over .08-.20	17.50-19.00	8.00- 9.00	.....	24c	27c	34c	21½c	28c	20.40c
302B	Over .08-.20	17.50-19.00	8.00- 9.00	Si 2.00-3.00.....	24c	27c	34c	21½c	28c	20.40c
303	.20 Max.	17.50-19.00	8.00- 9.00	S or Se .07 Min or Mo .60 Max	26c	29c	36c	27c	33c	22.10c
304	.08 Max.	17.50-19.00	8.00- 9.00	.....	25c	29c	36c	23½c	30c	21.25c
305	Over .08-.20	18.00-20.00	9.00-10.00	.....	25c	29c	36c	23½c	30c	21.25c
306	.08 Max.	18.00-20.00	9.00-10.00	.....	26c	31c	38c	25½c	32c	22.10c
307	Over .08-.20	20.00-22.00	10.00-12.00	.....	26c	31c	38c	25½c	32c	22.10c
308	.08 Max.	20.00-22.00	10.00-12.00	.....	28c	33c	40c	27½c	34c	23.80c
309	.20 Max.	22.00-26.00	12.00-14.00	.....	36c	40c	47c	37c	47c	30.60c
310	.25 Max.	24.00-26.00	19.00-21.00	.....	49c	52c	53c	48¾c	56c	41.65c
311	.25 Max.	19.00-21.00	24.00-26.00	.....	49c	52c	53c	48¾c	56c	41.65c
312	.25 Max.	27.00-31.00	8.00-10.00	.....	36c	40c	49c	....	....	30.60c
315	.15 Max.	17.00-19.00	7.00- 9.50	Cu. 1.00-1.50 Mo 1.00-1.50	36c	42c	46c	....	....	....
316	.10 Max.	16.00-18.00	14.00 Max.	Mo 2.00-3.00.....	40c	44c	48c	39¾c	48c	34.00c
317	.10 Max.	18.00-20.00	14.00 Max.	Mo 3.00-4.00.....	45c	49c	53c	44¾c	53c	38.25c
321	.10 Max.	17.00-20.00	7.00-10.00	Ti Min 4xC.....	29c	34c	41c	29¼c	38c	24.65c
325	.25 Max.	7.00-10.00	19.00-23.00	Cu 1.00-1.50.....	26c	30c	37c	26¼c	34c	22.10c
327	.25 Max.	25.00-30.00	3.00- 5.00	.....	31c	36c	42c	30¾c	41c	26.35c
329	.10 Max.	25.00-30.00	3.00- 5.00	Mo 1.00-1.50.....	36c	40c	44c	....	....	30.60c
330	.25 Max.	14.00-16.00	33.00-36.00	.....	49c	52c	53c	....	....	41.65c
343	Over .25	12.00-16.00	12.00-16.00	W 3.00.....	....	....	....	....	....	....
347	.10 Max.	17.00-20.00	8.00-12.00	Cb 10 x C.....	30c	35c	42c	30¼c	39c	25.50c
403	.12 Max.	11.50-13.00	.....	Turbine Quality.....	21½c	24½c	29½c	21¼c	27c	18.275c
405	.08 Max.	11.50-13.50	.....	Al .10-.20.....	20c	23c	28c	19¾c	25½c	17.00c
406	.12 Max.	12.00-14.00	.....	Al 4.00-4.50.....	23c	26c	31c	22¾c	31c	19.55c
410	.12 Max.	10.00-13.50	.....	.....	18½c	21½c	26½c	17c	22c	15.725c
414	.12 Max.	10.00-13.50	2.00 Max.	.....	18½c	21½c	26½c	17c	22c	15.725c
416	.12 Max.	12.00-14.00	.....	S or Se .07 Min or Mo .60 Max	19c	22c	27c	18¼c	23½c	16.15c
418	.12 Max.	12.00-14.00	.....	W 2.50-3.50.....	....	....	....	....	....	....
420	Over .12	12.00-14.00	.....	.....	24c	28½c	33½c	23¾c	36½c	20.40c
420F	Over .12	12.00-14.00	.....	S or Se .07 Min or Mo .60 Max	24½c	....	....	....	....	....
430	.12 Max.	14.00-18.00	.....	.....	19c	22c	29c	17½c	22½c	16.15c
430F	.12 Max.	14.00-18.00	.....	S or Se .07 Min or Mo .60 Max	19½c	22½c	29½c	18¾c	24½c	16.575c
431	.15 Max.	14.00-18.00	2.00 Max.	.....	19c	22c	29c	17½c	22½c	16.15c
434A	.12 Max.	14.00-18.00	.....	Si 1.00 Cu 1.00.....	19c	23c	30c	17½c	22½c	16.15c
438	.12 Max.	16.00-18.00	.....	W 2.50-3.50.....	....	....	....	....	....	....
439	.50-.65	8.00	.....	W 8.00.....	....	....	....	....	....	....
440	Over .12	14.00-18.00	.....	.....	24c	28½c	33½c	23¾c	36½c	20.40c
441	Over .15	14.00-18.00	2.00 Max.	.....	24c	28½c	33½c	23¾c	36½c	20.40c
442	.35 Max.	18.00-23.00	.....	.....	22½c	25½c	32½c	23c	28½c	19.125c
446	.35 Max.	23.00-30.00	.....	.....	27½c	30½c	36½c	28c	36½c	23.375c
501	Over .10	4.00- 6.00	.....	.....	8c	12c	15¾c	12c	17c	7.20c
502	.10 Max.	4.00- 6.00	.....	.....	9c	13c	16¾c	13c	18c	8.10c

Where definite carbon content .11 or under is specified for Types 302, 305 and 307, the price of Types 304, 306 and 308 respectively apply.
No specific composition limits within the above ranges may be placed on Types 302, 302B, 303, 305 and 307, except that carbon may be specified to a four point range within the above limits.
When Types 302 and 304 are specified with minimum chrome of 18%, add 0.50c per pound to the base price.

25-30 CHROMIUM IRON ALLOYS

MAKERS OF 25 TO 30 CHROMIUM IRONS

No.	MATERIAL Type No. in ( )		MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Allegheny 28	(446)	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 23-30; C, 0.35 max.; Mn, 1.0 max.; Ni, 1.0 max.	B, C, CR, HR, D, P, S, R, T, W
2	Amsco F-3		Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 27-29; C, 0.30; Si, 1.50 max.; Ni, 3.0 max.; Mn, 1.00 max.	C
3	Armco 27	(446)	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 23-30; C, 0.25 max.; Si, 1.0; Mn, 0.90	P, S
4	Avesta 831		A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 24; C, 0.20	HR, P, S, T, B
5	Bethadur 446	(446)	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 28; C, 0.25; Mn, 0.3; Ni, 0.25	B, HR
6	B & W 950		Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 26-30; C, 0.25 max.; Si, 1.50 max.	C
7	Cooper 19		Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 26-30; C, 0.20-0.50; Mn, 0.50	C
8	Cooper 19A		Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 26-30; C, 0.20-0.50; Ni, 2-3; Mn, 0.50	C
9	Croloy 27		Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 25-30; C, 0.2	CR, HR, T
10	Defiheat	(446)	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 23-30; C, 0.35 max.; Si, 1; Mn, 0.25-0.80; Ni; 0.50 max.	B, CR, HR, D, R, W
11	Duraloy A		Duraloy Co., Scottdale, Pa.	Fe; Cr, 28; C, 0.25; Mn, 0.50	B, C, CR, HR, D, P, S, R, T, W
12	Durco D-28		Duriron Co., Dayton, Ohio	Fe; Cr, 26-30; C, 0.25	C
13	Duro-Gloss C-4	(446)	Jessop Steel Co., Washington, Pa.	Fe; Cr, 28; C, 0.20; Mn, 0.25	B, CR, HR, D, P, S, R
14	Empire 21		Empire Steel Castings, Reading, Pa.	Fe; Cr, 27-29; C, 0.25; Mn, 0.4-0.5	C
15	Enduro HC	(446)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 23-30; C, 0.35; Mn, 0.50; Si, 0.50	B, C, CR, HR, D, P, S, R, T, W
16	Fahrite N-7		Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 25-30; C, 0.25-0.35; Ni, 3 max.	
17	Lesco HH	(446)	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 27; C, 0.20 max.; Si, 0.50 max.; Mn, 0.40	HR
18	Midvaloy 2802		Midvale Co., Nicetown, Philadelphia, Pa.	Fe; Cr, 28; C, 0.25; Ni, 1.5	B, C, HR, R
19	Miscrome 3		Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 28; C, 0.30; Ni, 1.00 max.; Mn, 0.60	C
20	Otisel 30		Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 23-30; C, 0.2-0.25; Mn, 1.0 max.	
21	Pyrocast		Pacific Fdry. Co., San Francisco, Calif.	Fe; Cr, 22-30; C, 1.75-2.00; Ni, 3.00 max.; Mo. 2.00 max.; Mn, 0.3-0.5	C
22	Rexistal 27		Crucible Steel Co., New York, N. Y.	Fe; Cr, 23-30; C, 0.35 max.	
23	Stainless Steel	(446)	Alloy Metal Wire Co., Prospect Pk., Pa.	Fe; Cr, 23-30; C, 0.25 max.	CR, D, R, W
24	Tisco 130		Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 28; C, 0.10 max.; Si, 2.0; Mn, 0.50	C
25	Uniloy 2825	(446)	Universal-Cyclops Steel Corp. Bridgeville, Pa.	Fe; Cr, 26-30; C, 0.25 max.; Mn, 0.3-0.5	B, HR, D, P, S, R, W
26	U. S. S. 27	(446)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 23-30; C, 0.35 max.; Mn, 1.00 max.; Ni, 1.00 max.; Si, 0.75 max.	B, CR, HR, D, P, S, R, W

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF 25 TO 30 CHROMIUM IRONS

No.	MATERIAL Type No. in ( )		Specific Gravity	Melting Point, °F.	Mean Coef. Therm. Exp., 32-212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Allegheny 28	(446)	7.6	2700	0.60	0.050	Annealed bar	75	45	20	40	29	150	Fair	Fair	F, R, W
2	Amsco F-3		7.5	2350-2630	1.00	0.059	As cast	40-60	30-45	0-2	0-5		170	Fair	Good	W
3	Armco 27	(446)	7.54	2710-2750	0.59	0.05	Annealed	80	50	23		29	175	Fair	Good	DD, F, R, W, B
4	Avesta 831		7.66		0.95	0.06	Air c'l'd from 1472° F.	70	51	35	60		180			
5	Bethadur 446	(446)		2700-2750	0.56		Annealed	90	50	20	37		187	Fair		
6	B & W 950		7.60	2700	0.56	0.03	Annealed	60	40	2-6			180	Good		
7	Cooper 19		7.6	2675	0.56	0.064	Cast	60	35	3	4	28	170	Good	Good	
8	Cooper 19A		7.6	2675	0.56	0.064	Cast	70	35	7	8	28	190	Good	Good	
9	Croloy 27		7.6	2650	0.52	0.059	Annealed tube	75-90	45-60	15-30		28-30	160-195	Fair	Fair	F, W
10	Defiheat	(446)	7.54	2600-2800	0.59	0.050	Annealed bar	80	50	30	50	28	165	Fair	Fair	R, W, B
11	Duraloy A		7.60	2650	0.67		As cast	40	30	0-1	0-2			Good	Good	F, R, W
12	Durco D-28						Cast	55	40				180	Fair	Fair	W
13	Duro-Gloss C-4	(446)					Annealed	90	55	25	55		171	Fair	Good	DD, F, R, W, B
14	Empire 21						Annealed casting	55	35	1-2	3-4		180	Fair	Poor	W
15	Enduro HC	(446)	7.54	2650-2700	0.53			75-90	45-60	20-30	40-50	29	140-185	Fair	Good	DD, F, R, W
16	Fahrite N-7		7.6		0.56		Annealed	75	60	3	3		180	Fair	Good	
17	Lesco HH	(446)	7.6	2804	0.57		Hot rolled bar	70	45	30	60		163	Fair	Fair	W, B
18	Midvaloy 2802		7.6		0.59		Cast	75-100	60-80	20-30	40-60		165-200	Fair		
19	Miscrome 3							60						Good	No	
20	Otisel 30		7.6		0.73	0.059	Annealed	70-80	30-40	5	6		170-190			R, W
21	Pyrocast		7.54	2550-2700			Cast	60-70	60-70	0	0		290-310	Good	Fair **	
22	Rexistal 27		7.65			0.059	Annealed	80-90	55-65	20-30	40-50		160-200	Machinable		R
23	Stainless Steel	(446)	7.60		0.54		Annealed	75-90	45-55	20-30	40-55		145-185	Fair	Good	DD, F, R, W, B
24	Tisco 130						Cast	40-60	30-40	0-3	0-5		200-220	Good	Fair	
25	Unilay 2825	(446)	7.65	2750	0.59		Annealed	75-90	45-50	20-30	40-50	29	160-200	Fair	Fair	R, W
26	U. S. S. 27	(446)		2710-2750	0.59	0.050	Annealed plate	75-90	45 55	25-35	45-60		160-200	Poor	Good	DD, F, R, W

** May be hardened to 600 Brinell for good abrasion resistance.

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

ABRASION-RESISTANT ALLOYS

MAKERS OF ABRASION-RESISTANT ALLOYS

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Amsco 459	Amer. Manganese Steel Div., Amer. Brake Shoe & Fdry. Co., Chicago Heights, Ill.	Fe; Cr; Mo	Weld rod
2	Amsco Mn Steel	Amer. Manganese Steel Div., Amer. Brake Shoe & Fdry. Co., Chicago, Heights, Ill.	Fe; Mn, 10–14; Si, 1.5 max.; C, 1–1.4	C, HR, W
3	Bethlehem 235	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Mn, 1.2–1.75; C, 0.35–0.50; Si, 0.20	B, HR, P, S.
4	Bethlehem 300	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Mn, 0.7–0.9; C, 0.75–0.85; Si, 0.20	B, HR, P, S
5	Carbon-Mn AR Steel	Jones & Laughlin Steel Corp', Pittsburgh, Pa.	Fe; C, 0.4–0.5; Mn, 1–1.7; Si, 0.1–0.3	HR, P, S, T, W, B
6	Colmonoy 1	Wall-Colmonoy Corp., Los Nietos, Calif.	Steel rod coated with crystals	Rod
7	Colmonoy 2	Wall-Colmonoy Corp., Los Nietos, Calif.	Fe; Cr, 5–8; C + Si, 4; B, 1.5–2	C, weld rod
8	Colmonoy 3	Wall-Colmonoy Corp., Los Nietos, Calif.	Fe; W, 15–22; Cr, 12–18; B, 3–5	Weld rod
9	Colmonoy 6	Wall-Colmonoy Corp., Los Nietos, Calif.	Ni, 63–73; Cr, 15–22; B, 3–5; Fe; C; Si	
10	Duraloy H	Duraloy Co., Scottdale, Pa.	Fe; Cr, 28; C, 2.75	C
11	Genesee 412	Symington-Gould Corp., Rochester, N. Y.	Fe; Mn, 11–14; C, 1.10	C
12	Hascrome	Haynes Stellite Co., Kokomo, Ind.	Fe; Cr, Mn	Rod
13	Haystellite	Haynes Stellite Co., Kokomo, Ind.	Tungsten carbide	Rod, inserts
14	Meehanite	Meehanite Metal Corp., Pittsburgh, Pa.	A process applicable to cast irons.[1]	C
15	Stellite 1	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	C, weld rod
16	Stellite 6	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	Weld rod
17	Stellite 12	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	Weld rod
18	Stellite J-Metal	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	C, tools

* Forms available: B, bars; C, castings; HR, hot rolled; P, plates; S, sheets; T, tubes; W, wire. [1] Other treatments improve resistance of castings to heat and corrosion.

PHYSICAL PROPERTIES OF ABRASION-RESISTANT ALLOYS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Amsco 459		2450–2600									500–600	Poor	Good	
2	Amsco Mn Steel	7.90	2500–2600	1.00		Water quench, 1850° F.	100–130	35–50	40–60	30–50			Difficult	Good	R, W
3	Bethlehem 235											235	Fair	Good	F, R, W
4	Bethlehem 300											300	Fair	Good	F, R, W
5	Carbon-Mn AR Steel	7.85	2680–2720	1.15	0.115	Plate	95	52	15	35			Fair	Good	R, W
6	Colmonoy 1											580	Difficult	Good	Coating
7	Colmonoy 2	7.49	2010–2060	0.93		Cast						600	Difficult	Good	W
8	Colmonoy 3	8.26	2140	0.51								635	Difficult	Good	W
9	Colmonoy 6	7.80				As cast	50					600	Difficult	Good	W
10	Duraloy H												Poor	Good	
11	Genesee 412			1.00	0.027	Cast	80–140		25–35	30–40		170–200	Difficult	Good	
12	Hascrome												Poor	Good	W
13	Haystellite												Poor	Excel.	W
14	Meehanite	7.40	2102–2138	0.72			25–55					202–650	Variable	Good	
15	Stellite 1	8.59	2282	0.80		Weld deposit	47		0		34.9	54[1]	Poor	Good	W, B
16	Stellite 6	8.38	2327	0.94	0.035	Cast	105		1		30.4	40[1]	Poor	Good	W, B
17	Stellite 12	8.40	2306	0.88		Weld deposit	76		0			48[1]	Poor	Good	Coating
18	Stellite J-Metal	8.76	2318	0.81		Cast	65		0		35.4	61[1]	Poor	Good	

* Methods of fabrication: F, flanging; R, riveting; W, welding. [1] Rockwell "C" hardness number.

AUSTENITIC CAST IRONS

Makers of Austenitic Cast Irons

No.	MATERIAL	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available
1	Doppley	Sowers Mfg. Co., Buffalo, N. Y.	Fe; Ni, 17–20; C, 3.0; Cr, 2.5; Si, 2.0; Mn, 0.8; S, 0.15; P, 0.1	Castings
2	Ni-Resist	International Nickel Co., New York, N. Y.	Fe; Ni, 12–15; Cu, 5–7; Cr, 1.5–4; Mn, 1–1.5; Si, 1.25–2; C, 2.75–3.1	Castings
3	Ni-Resist (Cu-free)	International Nickel Co., New York, N. Y.	Fe; Ni, 15–20; Cr, 2.5 max.; Mn, 1–1.5; Si, 0.6–2; C, 2.2–3	Castings
4	Tisco 160	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Ni, 12–15; Cu, 5–7; Cr, 1.5–4; Mn, 1; Si, 1.5; C, 3	Castings

Physical Properties of Austenitic Cast Irons

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm Exp., 32–212 °F. (Multiply by 10^{-6})	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication
1	Doppley						35–40							
2	Ni-Resist	7.5–7.6	2150–2275	1.0		Cast	20–35	2 max.		17–19	120–170	Good	Good	
3	Ni-Resist (Cu-free)	7.5–7.6	2150–2275	1.0		Cast	20–35	2 max.		17–19	120–170	Good	Good	
4	Tisco 160					Cast	20–35				120–170	Good		

HIGHLY ALLOYED STEELS

MAKERS OF HIGH CHROMIUM-NICKEL ALLOYS

No.	MATERIAL Type No. in ( )	MANUFACTURER	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Allegheny 25-20	Allegheny Ludlum Steel Corp., Pittsburgh, Pa.	Fe; Cr, 24-26; Ni, 19-21; C, 0.25 max.; Mn, 1.50 max.	B, C, CR, HR, D, P, S, R, T, W
2	Amsco F-1	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe, 44-50; Cr, 15-17; Ni, 34-36; Si, 1.5 max.; Mn, 1.0 max.; C, 0.50 max.	C
3	Amsco F-5	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe, 10-18; Cr, 17-19; Ni, 65-68; Si, 1.5 max.; Mn, 1.0 max.; C, 0.50 max.	C
4	Amsco F-6	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe, 21-28; Cr, 12-14; Ni, 59-62; Si, 1.5 max.; Mn, 1.0 max.; C, 0.50 max.	C
5	B & W 700	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 16-20; Ni, 62-68; C, 0.4-0.6	C
6	B & W 1100	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 24-26; Ni, 19-21; C, 0.25 max.	C
7	B & W 1200	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 7-9; Ni, 18-21; C, 0.40 max.	C
8	B & W 1300	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 15-17; Ni, 35-38; C, 0.50 max.	C
9	Calorized Steel	Calorizing Co., Wilkinsburg, Pa.	Fe, 95; Cr, 2.25; Mo, 1; Al, 35 (1/32 in. deep)	CR, D, R, T
10	Caloxo 15-35	Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 14-17; Ni, 33-37; C, as specified	C
11	Caloxo 25-20	Warman Steel Casting Co., Huntington Pk., Calif.	Fe; Cr, 23-27; Ni, 17-21; C, as specified	C
12	Chromax	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 19; Ni, 35	B, C, CR, HR, P, S, R, T, W
13	Cooper 18	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 10; Ni, 22; Mn, 0.50; C, 0.20	C
14	Cooper 20	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 15-18; Ni, 35-38; Mn, 0.5; C, 0.2-0.5	C
15	Cooper 21	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 15; Ni, 65; Mn, 0.5; C, 0.50 max.	C
16	Cooper 21A	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 15; Ni, 25; Mo, 2; Si, 1.25; Mn, 0.5; C, 0.20 max.	C
17	Cooper 21B	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 18; Ni, 22; Mo, 3; Si, 1; Mn, 0.5; Cu, 1; C, 0.07 max.	C
18	Cooper 21C	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 24; Ni, 20; Mo, 2; Cu, 2; Si, 1.25; Mn, 0.5, C, 0.12 max.	C
19	Cooper 25-20	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 23-27; Ni, 17-21; C, 0.20; Si, 2; Mn, 0.5	C
20	Croloy 25-20	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 24-26; Ni, 19-21; C, 0.1; Mn, 1.5 max.	CR, HR, T
21	Duraloy 15-35	Duraloy Co., Scottdale, Pa.	Fe; Cr, 15; Ni, 35; C, 0.50	B, C
22	Durco D-6	Duriron Co., Dayton, Ohio	Fe; Cr, 8-10; Ni, 19-22; C, 0.35 max.	C
23	Durimet	Duriron Co., Dayton, Ohio	Fe; Cr, 19; Ni, 22; Mo, 3.5; Si, 1.25; C, 0.07 max.	B, C, HR
24	Elcomet K	LaBour Co., Elkhart, Ind.	Fe; Cr, 24 Ni 22; Cu, 3.5; Mo, 2; Si, 1.25; C, 0.13	C
25	Empire 4	Empire Steel Castings, Reading, Pa.	Fe; Cr, 14-16; Ni, 34-36; C, 0.25 max.	C
26	Enduro NC 3 (310)	Republic Steel Corp., Cleveland, Ohio	Fe; Cr, 24-26; Ni, 19-21; C, 0.25 max.; Mn, 1.5	B, C, CR, HR, D, P, S, R, T, W
27	Fahrite N-1	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 15-18; Ni, 34-38; C, 0.45-0.55	C, R
28	Fahrite N-5	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 10-14; Ni, 59-62; C, 0.5-0.6	C
29	Fire Armor	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 15-19; Ni, 65-68	B, C, HR, P, S, R
30	Fire Armor B	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 11-13; Ni, 59-61	B, C, HR, P, S, R
31	Genesee 304	Symington-Gould Corp., Rochester, N. Y.	Fe; Cr, 17; Ni, 35; Mn, 0.65; C, 0.45	
32	Genesee 305	Symington-Gould Corp., Rochester, N. Y.	Fe; Cr, 17; Ni, 65; Mn, 0.6; C, 0.35	C
33	Hoskins 502 (cast)	Hoskins Mfg. Co., Detroit, Mich.	Fe; Cr, 18.5, Ni, 35; Si, 2.5; Mn, 1.5; C, 0.5	C
34	Hoskins 502	Hoskins Mfg. Co., Detroit, Mich.	Fe; Cr, 18.5; Ni, 35; Si, 1.5; Mn, 0.5; C, 0.15	B, CR, HR, D, W
35	Kanthal A-1	C. O. Jelliff Mfg. Corp., Southport, Conn.	Fe; Cr; Al; Co	W, CR
36	Kanthal A	C. O. Jelliff Mfg. Corp., Southport, Conn.	Fe; Cr; Al; Co	W, CR
37	Kanthal D	C. O. Jelliff Mfg. Corp., Southport, Conn.	Fe; Cr; Al; Co	W, CR
38	Lesco 25-20 (310)	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 25; Ni, 20; C, 0.20 max.; Si, 0.95 max; Mn, 0.40	B, CR, HR, D
39	Midvaloy 1735	Midvale Co., Philadelphia, Pa.	Fe; Cr, 17; Ni, 35 C, 0.35	C
40	Midvaloy 2520 (310)	Midvale Co., Philadelphia, Pa.	Fe; Cr, 25; Ni, 20	B, C, HR, R
41	Midvaloy ATV 1	Midvale Co., Philadelphia, Pa.	Fe; Cr, 14-15; Ni, 36; C, 0.35	B, C, HR, R
42	Midvaloy ATV 3	Midvale Co., Philadelphia, Pa.	Fe; Cr, 14; Ni, 26.5; W, 3.5; C, 0.48	B, C, HR, R
43	Milwaukee 15-35	Milwaukee Steel Fdry. Co., Milwaukee, Wis.	Fe; Cr, 14-16; Ni, 33-37; C, 0.45	C
44	Misco HN-2	Michigan Steel Casting Co., Detroit, Mich.	Fe; C, 0.70 max; Cr, 14; Ni, 60; Mn, 0.60	
45	Misco Metal	Michigan Steel Casting Co., Detroit, Mich	Fe; C, 0.50; Cr, 15; Ni, 35; Mn, 0.60	C, HR, P, S, B
46	National NA-2	National Alloy Steel Div., Blaw-Knox Co., Blawnox, Pa.	Fe; Cr, 17.5; Ni, 35; Si, 1.5; Mn, 0.8; C, 0.40	C, T
47	Nichrome	Driver-Harris Co., Harrison, N. J.	Fe, 25; Cr, 15; Ni, 60	C, CR, HR, D, P, S, T, W, B
48	Nichrome (Cast)	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 11-13; Ni, 59-61	C
49	Premier Nickel Chrome	Alloy Metal Wire Co., Prospect Pk., Pa.	Fe; Cr, 12; Ni, 65	CR, R, W
50	Pyrasteel 18	Chicago Steel Fdry. Co., Chicago, Ill.	Fe; Cr, 16; Ni, 25; Mn, 0.80; C, 0.35	C
51	Pyrasteel 20	Chicago Steel Fdry. Co., Chicago, Ill.	Fe; Cr, 18; Ni, 35; Mn, 0.80; C, 0.40	C
52	R-55	LaBour Co., Elkhart, Ind.	Fe; Cr, 10-14; Ni, 59-62	C, HR, P, S, W, B
53	Resistal 4 (311)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 19-21; Ni, 24-26; C, 0.25 max.	
54	Resistal 7 (310)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 24-26; Ni, 19-21; C, 0.25 max.	
55	Resistal 2600 (325)	Crucible Steel Co., New York, N. Y.	Fe; Cr, 7-10; Ni, 21-23; Cu, 1-1.5; C, 0.25 max.	
56	Simonds 25-20	Simonds Saw & Steel Co., Lockport, N. Y.	Fe; Cr, 25; Ni, 20	B, CR, HR, P, S, R
57	Simonds 35-15	Simonds Saw & Steel Co., Lockport, N. Y.	Fe; Cr, 15; Ni, 35	B, CR, HR, P, S, R
58	Sivyer 70	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 15-17; Ni, 34-36; C, 0.50 max.	C
59	Standard 15-35	Standard Alloy Co., Cleveland, Ohio	Fe; Cr, 15; Ni, 35; Si, 1.5; Mn, 0.7; C, 0.40	C
60	Thermalloy A	Electro-Alloys Co., Elyria, Ohio	Fe; Cr, 18-20; Ni, 62-65	C
61	Thermalloy B	Electro-Alloys Co., Elyria, Ohio	Fe; Cr, 15-18; Ni, 38-40	C
62	Thermalloy 72	Electro-Alloys Co., Elyria, Ohio	Fe; Cr, 12-15; Ni, 60-62	C
63	Tisco 105	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 25; Ni, 18; C, 0.20 max.; Si, 2 max.; Mn, 1.0 max.	C
64	Tophet C	Wilber B. Driver Co., Newark, N. J.	Fe; Cr, 15; Ni, 60	W & Ribbon
65	U. S. S. 25-20 (310)	Subsidiary Mfg. Cos. of U. S. Steel Corp., Pittsburgh	Fe; Cr, 24-26; Ni, 19-21; C, 0.25 max; Mn, 2 max.	
66	Worthite	Worthington Pump & Mach. Co., Harrison, N. J.	Fe; Cr, 20; Ni, 24; Si, 3.5; Mo, 3; Cu, 1.5; C, 0.07 max.	B, C, HR, R
67	X-ite	General Alloys Co., Boston, Mass.	Fe; Cr, 17-21; Ni, 37-40; Mn, 0.5-1; C, 0.4-0.8	B, C, S
68	Zerite	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 14-16; Ni, 34-36	B, C, HR, P, S, R

* Forms available: B, bars; C, castings; CR, cold rolled; HR, hot rolled; D, drawn; P, plates; S, Sheets; R, rods; T, tubes; W, wire.

PHYSICAL PROPERTIES OF HIGH CHROMIUM-NICKEL ALLOYS

No.	MATERIAL Type No. in ( )	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. (Multiply by 10^6)	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² (Multiply by 10^6)	Brinell Hardness	Machining Qualities	Abrasion Resistance	Methods of Fabrication*
1	Allegheny 25-20	7.94	2600	0.80	0.039	HR annealed bar	100	49	45–55	50–60	29.5	140–200	Fair	Fair	DD, F, R, W
2	Amsco F-1	7.9	2550–2650	0.7	0.03	Cast	50–70	40–50	4–8	4–8	26	150–180	Fair	Fair	W
3	Amsco F-5	8.0	2550–2650	0.9	0.035	Cast	50–70	35–45	20–40	20–40		180–200	Fair	Fair	W
4	Amsco F-6	Prop	erties similar	to Amsco	F-5										W
5	B & W 700	8.1			0.03	Cast	60	46	2–4	2–4		170–190	Good		
6	B & W 1100	7.3	2600	0.85		Annealed	65–75	30–40	15–40	15–60		180–200	Fair		
7	B & W 1200	8.0	2700	0.95	0.07	Annealed	50–60	25–30	10–20	15–25		150	Good		
8	B & W 1300	7.92	2550	0.75	0.04	Cast	60–70	35–45	3–10	5–15		180	Good		
9	Calorized Steel					Tube, calorized	60		25				Poor	Good	W
10	Caloxo 15-35						55–65	35–40	10–15				Fair	Good	
11	Caloxo 25-20		2550–2685			Cast and annealed	72–80	35–42	35–40			135–145	Fair	Fair	
12	Chromax	7.9	2520		0.031	Wire and strip	70–150	30–40	30				Good	Good	DD, F, R, W B
13	Cooper 18	8.0	2675	1.0	0.074	Cast	79	46.5	23	24	28	140	Good	Fair	
14	Cooper 20	7.95	2700	0.75	0.028	Cast	65	40	7	8	28	165	Good	Fair	
15	Cooper 21	8.20	2500	0.76	0.033	Cast	60	45	3	2	28	170	Good	Fair	
16	Cooper 21A	7.9	2700	0.75	0 04	Cast	75	43	20	25	28	160	Good	Fair	
17	Cooper 21B	7.85	2700	0.80	0.05	Cast	70	30	40	40	28	150	Good	Fair	
18	Cooper 21C	7.90	2700	0.85	0.055	Cast	75	35	40	45	28	150	Good	Fair	
19	Cooper 25-20	7.85	2700	0.95	0.03	Cast	65	50	15	12	28	190	Good	Fair	
20	Croley 25-20	7.9	2540–2600	0.89	0.039	Annealed tube	75 min.	30	40 min.		29.7	200 max.	Fair	Fair	DD, F, W
21	Duraloy 15-35			0.75	0.025	Cast	60		5	6		170–180	Good		
22	Durco D-6					Sand castings	65–80	30–40	30–40	35–50		120–140	Good	Good	W
23	Durimet	7.85	2650	0.78	0.05	Sand castings	65–75	30–40	35–50	40–55		130–150	Fair	Fair	W
24	Elcomet K												Fair	Yes	R, W, B
25	Empire 4					Cast, annealed	60	30	30-35	35–40		180	Fair	Poor	W
26	Enduro NC-3 (310)	8.02	2500–2600	0.8			90–110	40–60	45–55	50–60		145–210	Fair	Fair	DD, F, R, W
27	Fahrite N-1	7.94				Cast	60	30	5	5		165	Good	Fair	
28	Fahrite N-5	8.13				Cast	65	30	6	6		176	Good	Fair	
29	Fire Armor	8.14		0.78		Cast	65	34	4.5	5.5		190	Fair		
30	Fire Armor B	8.14		0.78		Cast	65	34	4.5	5.5		181	Fair		
31	Genesee 304												Fair		
32	Genesee 305												Fair		
33	Hoskins 502 (cast)	7.84	2400–2450		0.036	Cast	60–68	45	2–5			150–185	Good	Good	W
34	Hoskins 502	8.0	2500		0.036	Rod	100–110	75–85	50			165–210	Good	Good	DD, R, W
35	Kanthal A-1	7.1	2800			Annealed	100	89		64		230	Fair		W, CR
36	Kanthal A	7.15	2780			Annealed	100	89	13	65		230	Fair		W, CR
37	Kanthal D	7.25	2780			Annealed	100	89		65		200	Fair		W, CR
38	Lesco 25-20 (310)					HR bar and forging	117	57	40	54		217	Fair	Fair	DD, F, R, W, B
39	Midvaloy 1735	7.93		0.74		Cast	55–65	40–45	5–12	10–20		150–170	Fair	Fair	
40	Midvaloy 2520 (310)	7.80		0.8			85–100	40–50	25–40	24–50		170–200	Fair	Fair	
41	Midvaloy ATV 1	8.05	2640		0.020	Wrought	88–110	50–68	20–35	30–54		170–185	Good	Good	
						Cast	55–65	34–40	8–12	8–12					
42	Midvaloy ATV 3	8.12		0.78		Bars	100–112	45–70	24–33	40–45		185–238	Good		B, C, HR, R
43	Milwaukee 15-35	8.0	2550–2650	0.65	0.027		60–70	40–50					Poor		
44	Misco HN-2					Cast	75	45	3	5	22.4	200	Good		R, W
45	Misco Metal			0.76		Cast	60	40	3	4	23	200	Good	Yes	W
46	National NA-2	7.93	2590	0.75	0.020	Cast, annealed	65	55	8	15	32	180	Fair	Good	W
47	Nichrome	8.25	2462	0.76	0.03	Wrought	100	60	35	50			Good	No	DD, F, R, W, B
48	Nichrome (Cast)	8.15	2460	0.62	0.033	Cast	65		2.0	3.5			Good	No	
49	Premier Nickel Chrome	8.24				Ann'l'd rod, wire strip	90	35	35–40	65–75			Poor	Good	F, R, W, B
50	Pyrasteel 18			0.9	0.065		62	37	5	5		160	Fair	Fair	
51	Pyrasteel 20				0.035		65	35	5	5.5		155	Good	Good	
52	R-55						67	55	2	3		190	Fair	Yes	R, W, B
53	Rezistal 4 (311)	7.84		0.90		Annealed	90–110	45–50	30–40	35–45	28–30	160–190	Fair		W, R
54	Rezistal 7 (310)	7.72		0 89		Annealed	100–110	45–55	45–55	50–60	28–30	150–180	Fair		W, R
55	Rezistal 2600 (325)	7.98		0.93	0.074	Annealed	85–95	45–55	30–40	45–55	28–30	160–190	Machinable		W, R
56	Simonds 25-20	7.93	2550–2700	1.35	0.025	Annealed, 2 in. dia.	96	48	54	63	29.5	149	Good	Good	DD, F, R, W, B
57	Simonds 35-15	7.95	2550–2700	1.3	0.027	Annealed, 2 in. dia.	92	40	43.5	63	29	137	Good	Good	DD, F, R, W, B
58	Sivyer 70					Cast	60–70		2–7	2–8		200–225	Fair	Fair	
59	Standard 15-35	8.06	2615	0.75	0 025	Cast	85	55	20	6		180–195	Fair	Good	W
60	Thermalloy A			0.98								170–240			
61	Thermalloy B			1.10								170–240			
62	Thermalloy 72			0.98								170–240			
63	Tisco 108					Cast	80–90	35–45	15–25	15–25		160–180	Fair	Fair	
64	Tophet C	8.2	1650	1.37		Wire	95–175								
65	U. S. S. 25-20 (310)		2500–2600	0.80	0.033	Annealed rd. bar	100–110	40–55	45–55	50–60		150–210	Poor	Good	DD, F, R, W
66	Worthite	7.85		0.78		Cast	72	33	40	40		125–150	Good	Fair	R, W
						Rolled	97	48	45	57		170			
67	X-ite	8.05	2700–2800	0.69	0.014	Cast	60–80	40–50	4	3	30	210	Good	Good	W
68	Zurite	8.05		0.83		Cast	65	40	5	4	26.4	168	Fair		

* Methods of fabrication: DD, deep drawing; F, flanging; R, riveting; W, welding; B, brazing.

GLASS, GLASS-LINED and FUSED SILICA

PHYSICAL PROPERTIES OF BOROSILICATE GLASS, FUSED QUARTZ AND FUSED SILICA

MATERIAL	Specific Gravity	Specific Volume, Cu. in. per lb.	Tensile Strength, Lb. per sq. in.	Modulus of Elasticity, Lb. per sq. in. (Multiply by 10^6)	Hardness*	Thermal Expansion Per °F. (Multiply by 10^{-6})	Thermal Cond., Cal. per sec., cm^2, C., cm (Multiply by 10^4)	Specific Heat, Cal. per °C., gm.	Softening Point, °F.	Breakdown Voltage, 60 cycles, v. per mil	Dielectric Constant, 60 cycles	Refractive Index, n_{AD}	Transparency†	Forms Available**
Borosilicate glass	2.23	12.4	10,000	98	....	0.32	24.5	0.20	1,505	3,200 (0.1 in.)	4.6	1.47	T, TL	S, R, T, other
Fused quartz	2.20	12.6	6,000	105–126	4.9	0.054	35	0.25	2,600	500 (¼ in.)	4.2	1.459	T	S, R, T, other
Fused silica	2.07	13.4	1,700	94–114	....	0.054	25	.....	2,600	250 (¼ in.)	3.7	....	TL, O	S, R, T, other

* Hardness: 2.5 mm. ball, 25 kg. load, depth in 1/200 mm. † T = transparent; TL = translucent; O = opaque. ** S = sheets; R = rods; T = tubes.

MAKERS OF GLASS, GLASS-LINED AND FUSED SILICA EQUIPMENT

MANUFACTURER (Name and Address)	Composition, Forms Available	MANUFACTURER (Name and Address)	Composition, Forms Available
Alsop Engineering Co., New York, N. Y.	Glass-lined steel tanks and mixers	Hanovia Chemical & Mfg. Co., Newark, N. J.	Transparent fused quartz
Amersil Corp., Hillside, N. J.	Fused silica ware such as pans, pipes, gas coolers, absorbers	Metal-Glass Products Co., Belding, Mich.	Glass enameled steel equipment
Corning Glass Works, Corning, N. Y.	Special heat- and corrosion-resisting borosilicate glass supplied in various forms: pipe, columns, etc.	Owens-Corning Co., Toledo, Ohio	Fibrous glass filter cloths
Edge Moor Iron Works, Edge Moor, Dela.	Glass enameled steel equipment	The Pfaudler Co., Rochester, N. Y.	Wide variety of standard and special glass-enameled steel equipment — various formulas
Ertel Engineering Co., New York, N. Y.	Glass enameled tanks	A. O. Smith Corp., Milwaukee, Wis.	Glass-enameled steel equipment
General Electric Co., Schenectady, N. Y.	Transparent fused quarts in various small sized articles	The Thermal Syndicate, Brooklyn, N. Y.	Fused silica (non-transparent) supplied in various large forms; fused quarts (transparent) in smaller sizes
Glascote Co., Euclid, Ohio	Glass-enameled steel equipment	Vitreous Enameling & Stamping Co., New York, N. Y.	Enameled specialties, tanks

CHEMICAL BRICK, STONEWARE and CEMENTS

Physical Properties of Chemical Stoneware

The accompanying table, which has been prepared for us by the General Ceramics Co., gives the physical properties of an average grade of chemical stoneware. It should be emphasized here that "chemical stoneware" is not the name of a definite material, such as an alloy, but a generic term applied to a wide variety of ceramic compositions, and hence that in any particular composition designed to give optimum properties in one respect, it will ordinarily be impossible to secure optimum properties in all other respects.

Specific gravity	2.2	Modulus of elasticity, lb. per sq. in.	8×10^6
Hardness, scleroscope	100	Specific heat	0.2
Ultimate tensile strength, lb. per sq. in.	2,000	Thermal conductivity, B.t.u. per hr., sq. ft., °F., in.	0.833
Ultimate compressive strength, lb. per sq. in.	80,000	Linear thermal expansion, per °F.	2×10^{-6}
Modulus of rupture, lb. per sq. in.	5,000	Water absorption, per cent	0-4

MAKERS OF ACIDPROOF BRICK AND CHEMICAL STONEWARE

MANUFACTURER (Name and Address)	Materials	MANUFACTURER (Name and Address)	Materials
Acme Brick Co., Fort Worth, Tex.	Acidproof brick	Kewaunee Mfg. Co., Kewaunee, Wis.	Karcite carbon-filled acidproof ceramic
Alabama Clay Products Co., Birmingham, Ala.	Acidproof brick	Maurice A. Knight, Akron, Ohio	Chemical stoneware of all types
Alberene Stone Corp. of Va., New York, N. Y.	Acidproof stone	Laclede-Christy Clay Prod. Co., St. Louis, Mo.	Acidproof brick
Atlas Mineral Products Co., Mertztown, Pa.	Acidproof brick construction	McLain Fire Brick Co., Pittsburgh, Pa.	Acidproof brick
Belden Brick Co., Canton, Ohio	Acidproof brick	McLeod & Henry Co., Troy, N. Y.	Acidproof brick
Buckeye Pottery Co., Macomb, Ill.	Acidproof ceramics	Metropolitan Paving Brick Co., Canton, Ohio.	Acidproof brick
Champion Porcelain Co., Detroit, Mich.	Special porcelain shapes, impellers, nozzles, etc.	National Carbon Co., Inc., Cleveland, Ohio	Carbon brick
Charlotte Chemical Labs., Charlotte, N. C.	Acidproof brick, rings	North American Refractories Co., Cleveland, Ohio	Acidproof brick
Claycraft Co., Columbus, Ohio	Acidproof brick	Parker-Russell Mining & Mfg. Co., St. Louis, Mo.	Acidproof brick
Corhart Refractories Co., Louisville, Ky.	Acidproof brick	Patterson Foundry & Machine Co., East Liverpool, Ohio	Acidproof lining blocks and grinding balls
Custodis Construction Co., New York, N. Y.	Acidproof brick construction, towers, tanks	Quigley Co., New York, N. Y.	Acidproof brick
Electro-Chemical Supply & Engineering Co., Paoli, Pa.	Acidproof brick and masonry construction	Robinson Clay Product Co. of N. Y., New York, N. Y.	Acidproof and vitrified sewer tile
Filtros, Inc., East Rochester, N. Y.	Acidproof mineral as plates, cylinders, etc.	Southern Clay Mfg. Co., Chattanooga, Tenn.	Acidproof brick
General Ceramics Co., New York, N. Y.	Chemical stoneware of all types	Thornton Fire Brick Co., Clarksburg, W. Va.	Acidproof brick
General Refractories Co., Philadelphia, Pa.	Acidproof tower packing, brick	Uhl Pottery Co., Huntington, Ind.	Acidproof ceramics
Harbison-Walker Refractories Co., Pittsburgh, Pa.	Acidproof brick	United States Stoneware Co., Akron, Ohio	Chemical stoneware of all types
B. Mifflin Hood Co., Daisy, Tenn.	Acidproof tower packings and flooring tiles		
Ironton Fire Brick Co., Ironton, Ohio	Acidproof brick		

MAKERS OF CEMENTS AND PUTTIES FOR ACIDPROOF BRICK AND STONEWARE

MANUFACTURER (Name and Address)	Trade Names	Compositions, Applications, Types
Anti-Hydro Waterproofing Co., Newark, N. J.	Anti-Hydro	Water-, acid-, alkali-, oil-resisting concrete mix
Atlas Mineral Products Co., Mertztown, Pa.	Tegul-Vitrobond,-Mineralead, Tiloset, Korez, G. K., others	Thiokol-sulphur-base, chemical-setting silicate and resin-base and other cements for all acidproof construction
Charlotte Chemical Labs., Charlotte, N. C.	Charlab, Acidpruf, Carolina	Standard and chemical-setting silicate cements; acidproof putty
Chemical Construction Corp., New York, N. Y.	Acipruf	Acidproof cement
Custodis Const. Co., New York, N. Y.	Penchlor, Asplit, Kabe mortar	See under Pennsylvania Salt Mfg. Co.
Electro-Chemical Supply & Engineering Co., Paoli, Pa.	Duro Standard, Special, Triple X	Silicate cements for all acid conditions; also water and steam
Filtros, Inc., East Rochester, N. Y.	Filtros	Acidproof cement
General Ceramics Co., New York, N. Y.	Acidproof Nos. 1, 6, 7, 8	Silicate cements and linseed oil- and asphalt-base putties
B. F. Goodrich Rubber Co., Akron, Ohio	Plastikon	Rubber-base putty
The Haveg Corp., Newark, Del.	Havegit 41, 43	Self-hardening phenolic resin cements for acids
M. W. Kellogg Co., New York, N. Y.		Acidproof cement
Maurice A. Knight, Akron, Ohio	Knight	Silicate cements for strong acids
Johns-Manville Corp., New York, N. Y.	J-M	Caulking compound
Nukem Products Co., New York, N. Y.	Basolit	Sulphur-base cement for acids
Paraffine Cos., San Francisco, Calif.		Acidproof cement
Patterson Foundry & Machine Co., East Liverpool, Ohio	Porox Cement	Silicate cement for strong acids
Pecora Paint Co., Philadelphia, Pa.	Acitite, Acichlor, Cushion Putty	Slow- and quick-drying cements and elastic putties for acids
Pennsylvania Salt Mfg. Co., Philadelphia, Pa.	Penchlor, Asplit	Chemical-setting silicate cement; self-hardening resin cement
Philadelphia Quartz Co., Philadelphia, Pa.	"S" Brand Sodium Silicate	1:3.86 ratio sodium silicate for acidproof cements
Quigley Co., New York, N. Y.	Acidproof Nos. 1 and 2	Silicate cements for acid gases and mineral acids
H. H. Robertson Co., Pittsburgh, Pa.	Asphaltic Fibre Putty	Caulking compound for general resistance
The Sullivan Co., Memphis, Tenn.	Acidol, Sulsilo	Pouring cements and pre-mixed silicate cements for strong acids
Sauereisen Cements Co., Sharpsburg, Pa.	Insa-Lute, Acidproof	Standard and quick-setting silicate cements, etc.
United States Stoneware Co., Akron, Ohio	U. S. Standard, Pre-Mixt, Calkt ite and others	Silicate cements of all types, resin cements, putties, etc.

REFRACTORY MATERIALS

PHYSICAL PROPERTIES OF REFRACTORY MATERIALS

(Complete revision of earlier Chem. & Met. data, compiled by L. J. Trostel, General Refractories Co., Baltimore, with additional material on kaolin super duty and insulating refractories supplied by the Babcock & Wilcox Co., New York.)

Type of Brick	Silica	High Heat Duty (No. 1) Fireclay	Super Duty Fireclay	Super Duty Kaolin	Alumina-Diaspore, 70 Per Cent Al_2O_3	Silli-manite (Mullite)	Chrome	Unburned Chrome [1]	Magne-site	Unburned Magne-site [1]	Bonded Silicon Carbide (Grade A)	Bonded Fused Alumina	Kaolin Insul. Refr. (2,600°F.)
Typical composition, per cent													
SiO_2	96	50–57	52	52	22–26	35	6	5	3	5	7–9	8–10	57.7
Fe_2O_3	1	1.5–2.5	1	0.6	1–1.5	0.5	.....	.....	6	8.5	0.3–1	1–1.5	2.4
FeO	.....	.....	.....	.....	.....	.....	15	12	.....	.....	.....	.....	.....
Al_2O_3	1	36–42	43	45.4	68–72	62	23	18	2	7.5	2–4	85–90	36.8
TiO_2	.....	1.5–2.5	2	1.7	3.5	1.5	.....	.....	.....	.....	1	1.5–2.2	1.5
CaO	2	.....	.....	0.1	.....	.....	.....	.....	3	2	.....	.....	0.6
MgO	.....	.....	.....	0.2	.....	.....	17	32	86	64	.....	.....	0.5
Cr_2O_3	.....	.....	.....	.....	.....	.....	38	30	.....	10	.....	.....	.....
SiC	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	85–90	.....	.....
Flux [2]	.....	1–3.5	2	.....	1–1.5	0.5	.....	.....	.....	.....	1.5	0.8–1.3	.....
P.C.E. (with approx. equivalent temp., °F.) [3]	31–32 (3,056–3,092°)	31–33 (3,056–3,173°)	33–34 (3,173–3,200°)	34 (3,200°)	36 (3,290°)	37–38 (3,308–3,335°)	41+ (3,575°+)	41+ (3,578°+)	41+ (3,578°+)	41+ (3,578°+)	39 (3,389°)	39+ (3,389°+)	29–30 (2,984–3,002°)
Deformation under load, [4] per cent (at lb. per sq. in. and temp., °F., shown)	Shears 25 p.s.i. 2,900°	2.5–10* 25 p.s.i. 2,460°	2–4† 25 p.s.i. 2,640°	0.5† 25 p.s.i. 2,640°	1–4† 25 p.s.i. 2,640°	0.0–0.5† 25 p.s.i. 2,640°	Shears 28 p.s.i. 2,740°	Shears 28 p.s.i. 2,955°	Shears 28 p.s.i. 2,765°	Shears 28 p.s.i. 2,940°	0–1 50 p.s.i. 2,730°	1 50 p.s.i. 2,730°	0.3 10 p.s.i. 2,200°
Resistance to spalling, per cent loss in appropriate A.S.T.M. Panel Test	Poor	5–20	0–4	No loss	No loss	No loss	Poor	Fair	Poor	Fair	Good	Good	Good
Permanent linear change on reheating [5] (after 5 hr. at temp., °F., shown)	(+) 0.5–.8 2,640°	(±) 0–1.5 2,550°	(±) 0–1.5 2,910°	(−) 0.75–1 2,910°	(−) 2–4 2,910°	(−) 0–0.8 2,910°	(−) 0.5–1 3,000°	(−) 0.5–1.0 3,000°	(−) 1–2 3,000°	(−) 0.5–1.5 3,000°	(+) 2 [6] 2,910°	(+) 0.5 2,910°	(−) 0.2 2,600°
Porosity (as open pores), per cent	20–30	15–25	12–15	18	34–38	20–25	20–26	10–12	20–26	10–12	13–28	20–26	75
Weight per brick (std. 9 in. straight), lb.	6.5	7.5	8.5	7.7	7.5	8.5	11	11.3	10	10.7	8–9.3	9–10.6	2.25
Specific heat (60–1,200°F.)	0.23	0.23	0.23	0.22	0.23	0.23	0.20	0.21	0.27	0.26	0.20	0.20	0.22
Relative slag resistance [7]													
Acid steel slag	Good	Fair	Fair	Fair	Good	Good	Poor	Poor	Poor	Poor	Good	Good	Poor
Basic steel slag	Poor	Poor	Poor	Poor	Fair	Fair	Good	Good	Good	Good	Good	Good	Poor
Mill scale	Fair	Poor	Fair	Good [8]	Fair	Fair	Good	Good	Good	Good	Fair	Fair	Good [8]
Coal ash slag	Poor	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Good	Good	Good	Good	Poor

[1] Made by hydraulic pressing. [2] Includes CaO + MgO + alkalis. [3] Pyrometric Cone Equivalent; terms "fusion," "softening," "deformation," and "melting" points heretofore loosely used. [4] Data marked (*) are from A.S.T.M. test C 16-36 with High Heat Duty time-temperature schedule; those marked (†) are from same test with Super Duty time-temperature schedule; others determined by other commonly used tests. [5] (+) means expansion; (−) means shrinkage. [6] Oxidizing atmosphere. [7] Ratings affected somewhat by varying temperatures and type of atmosphere prevailing. Resistance to coal ash slag affected by furnace temperature as well as analysis and fusion point of slag. [8] To 2,400° F.

REPRESENTATIVE MAKERS OF REFRACTORIES AND HIGH TEMPERATURE MORTARS

MANUFACTURER (Name and Address)	Principal Types
Acme Brick Co., Ft. Worth, Tex.	Fireclay refrs.
Alberene Stone Corp. of Va., New York, N. Y.	Refractory linings
American Crucible Co., Shelton, Conn.	Graphite crucibles, silica and mullite refrs.
Armstrong Cork Co., Lancaster, Pa.	Refr. insul. brick, h.t. mortars
Babcock & Wilcox Co., New York, N. Y.	Glass plant refrs., h.t. mortars, plastic refrs., insulating and kaolin refrs.
Bartley Crucible & Refr. Co., Trenton, N. J.	Graphite crucibles, firebrick, magnesite refrs.
Beteon Plastic Fire Brick Co., Buffalo, N. Y.	H.t. mortars, plastic refrs.
Botfield Refractories Co., Philadelphia, Pa.	Chrome, firebrick, plastic refrs., h.t. mortars
Philip Carey Co., Lockland, Ohio	H.t. mortars, insulations
Carborundum Co., Perth Amboy, N. J.	Silicon carbide, aluminum oxide and fused cast refrs. and h.t. mortars
Champion Spark Plug Co., Detroit, Mich.	Sillimanite plastic refrs., electric furnace refrs.
Corhart Refractories Co., Louisville, Ky.	H.t. mortars, electro-cast mullite refrs.
Corundite Refractories, Inc., Massillon, Ohio.	Firebrick, h.t. mortars, plastic refrs, alumina, silica and mullite refrs.
Denver Fire Clay Co., Denver, Colo.	Firebrick, h.t. mortars, plastic refrs., fireclays
W. S. Dickey Clay Mfg. Co., Kansas City, Mo.	Fireclay refrs.
Joseph Dixon Crucible Co., Jersey City, N. J.	Graphite crucibles
Ebret Magnesia Mfg. Co. Valley Forge, Pa.	H.t. mortar
Electro Refrs. & Alloys Corp., Buffalo, N. Y.	Mullite, fused alumina, silicon carbide and magnesia refrs.
Emsco Refractories Co., Vernon, Calif.	Firebrick, glass plant refrs., h.t. mortars
The Exolon Co., Blasdell, N. Y.	Silicon carbide, alumina refrs.
General Abrasive Co., Niagara Falls, N. Y.	Alumina and silicon carbide
General Ceramics Co., New York, N. Y.	Special refrs.
General Refractories Co., Philadelphia, Pa.	Fired and unfired chrome and magnesite, firebrick, h.t. mortars, plastic and silica
A. P. Green Fire Brick Co., Mexico, Mo.	Firebrick, h.t. mortars, plastic refrs., fireclays.
Harbison-Walker Refrs. Co., Pittsburgh, Pa.	Firebrick, h.t. mortars, silica, various basic and special refrs.
Haws Refractories Co., Johnstown, Pa.	Various
Illinois Clay Products Co., Goose Lake, Ill.	Firebrick, h.t. mortars, insulating cements, coatings and brick
Johns-Manville, New York, N. Y.	H.t. mortars and plastic refrs.
Laclede-Christy Clay Prod. Co., St. Louis, Mo.	Firebrick, h.t. mortars, plastic refrs., glass plant refrs., fireclays
E. J. Lavino & Co., Philadelphia, Pa.	Chrome and magnesite refrs., h.t. mortars, silica refrs., fireclays
Massillon Refractories Co., Massillon, Ohio.	Firebrick, h.t. mortars, plastic refrs., special, compositions
McLain Fire Brick Co., Pittsburgh, Pa.	Various
McLeod & Henry Co., Troy, N. Y.	Firebrick, h.t. mortars, plastic refrs., fireclays
Mullite Refractories Co., Shelton, Conn.	H.t. mortars, plastic refrs., mullite refrs.
National Carbon Co., Inc., Cleveland, Ohio.	Carbon refrs.
Niles Fire Brick Co., Niles, Ohio	Firebrick, insulating refrs.
North American Refrs. Co., Cleveland, Ohio.	Firebrick, h.t. mortars, plastic and silica refrs., fireclays
Norton Co., Worcester, Mass.	H.t. mortars, silicon carbide, fused alumina, magnesia and mullite refrs.
Pacific Clay Products Co., Los Angeles, Calif.	Plastic refrs.
Pyro Clay Products Co., Oak Hill, Ohio.	Glass plant refrs.
Quigley Co., Inc., New York, N. Y.	Firebrick, insulating refrs., super firebrick, h.t. mortars, plastic refrs.
Ramtite Co., Chicago, Ill.	H.t. mortars
Refractory & Insulation Corp., New York, N.Y.	H.t. mortars
Robinson Clay Product Co. of N. Y., New York, N. Y.	H.t. mortars, firebrick and clay, insulating refrs.
Ross Tacony Crucible Co., Philadelphia, Pa.	Graphite crucibles
St. Louis Fire Brick & Insulation Co., Huntington Park, Calif.	Various
Seaboard Refrs. Co., Perth Amboy, N. J.	Firebrick, h.t. mortars, plastic and insulating refrs., silicon carbide and mullite refrs.
Chas. Taylor Sons Co., Cincinnati, Ohio.	Firebrick, glass plant and insulating refrs., sillimanite
M. D. Valentine & Bro. Co., Woodbridge, N. J.	Firebrick
Vitrefrax Corp., Los Angeles, Calif.	Glass plant refrs. firebrick, h.t. mortars, plastic refrs., fireclays

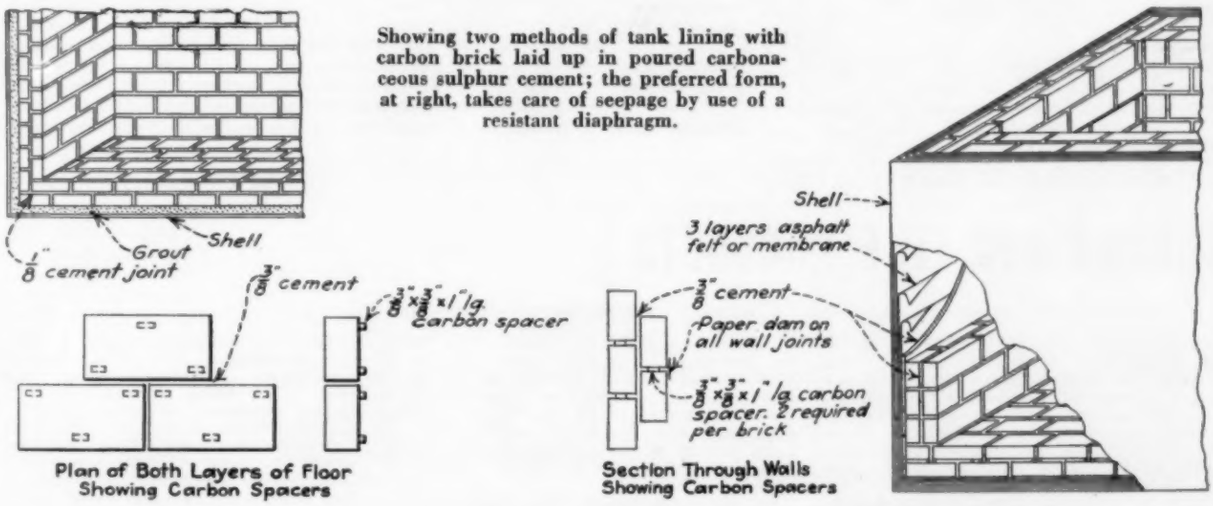
STRUCTURAL CARBON and GRAPHITE

PHYSICAL PROPERTIES OF IMPERVIOUS AND POROUS CARBON AND GRAPHITE

MATERIAL	Apparent Density	Pounds per Cu. Ft.	Porosity, Per Cent	Tensile Strength, Lb. per sq. in.	Compressive Strength, Lb. per sq. in.	Transverse Strength, Lb. per sq. in.	Elastic Modulus, Lb. per sq. in. (Multiply by 10^{-6})	Specific Resistance, Ohms per in.^{3}	Coeff. Thermal Exp. per °F. (Multiply by 10^{-6})	Thermal Conductivity, B.t.u. per hr., sq. ft., °F., ft.
Impervious carbon tubes										
⅛–2 in. I.D. inc.	1.77	110.	1.2	1,700	10,500	4,170	29.0	0.00164	0.27	3.0
Over 2 in. I.D.	1.76	110.	3.2	2,000	10,500	4,640	26.0	0.0016	0.33	2.8
Impervious graphite tubes										
⅛–2 in. I.D. inc.	1.86	116.	0.9	2,600	8,900	4,650	23.0	0.00034	0.23	85.
Over 2 in. I.D.	1.91	119.	0.4	2,350	10,500	4,960	21.0	0.00033	0.24	75.
Porous carbon										
C	1.34	83 6	35.7	670	3,210	1,690	>1.2	0.0020	0.06	3.0
H	1.15	71.7	41.9	230	930	610	>1.2	0.0044	0.14	1.8
50	1.05	65.5	50.0	150	860	430	>1.2	0.0071	0.27	1.4
40	1.04	64.8	48.	130	1,060	390	>1.2	0.0058	0.27	1.00
30	1.04	64.8	48.	135	790	330	>1.2	0.0074	0.27	1.00
20	1.03	64.2	48.	105	820	270	>1.2	0.0063	0.27	1.00
10	1.03	64.2	48.	110	240	240	1.2	0.0080	0.27	1.00
Porous graphite										
C	1.35	84.3	35 0	640	1,780	1,300	....	0.0005	0.06	60.
H	1.13	70.5	41.9	210	760	330	....	0.0012	0.09	50.
50	1.05	65.5	50.0	.....	.....	.....	....	....	0.21	45.
40	1.04	64.8	48.	120	510	230	....	0.0014	0.21	45.
30	1.04	64.8	48.	110	520	220	....	0.0017	0.21	40.
20	1.03	64.2	48.	60	320	140	....	0.0020	0.21	30.
10	1.03	64.2	48.	00	290	160	....	0.0014	0.22	20.

PHYSICAL PROPERTIES OF STRUCTURAL CARBON AND GRAPHITE (AVERAGE VALUES)

MATERIAL	Apparent Density	Pounds per Cu. Ft.	Porosity, Per Cent	Tensile Strength, Lb. per sq. in.	Compressive Strength, Lb. per sq. in.	Transverse Strength, Lb. per sq. in.	Long. Elastic Modulus, Lb. per sq. in. (Multiply by 10^6)	Specific Resistance, Ohms per in^3	Long. Coeff. Thermal Exp. per °F. (Multiply by 10^{-6})	Thermal Conductivity, B.t.u. per hr., sq. ft., °F., ft.
Carbon										
Electric furnace electrodes										
8 in. dia.	1.54	96.0	23.3	660	2,920	1,320	5.5	0.0013	0.13	6.0
10–14 in. dia. inc.	1.525	95.0	22.1	470	2,120	950	5.4	0.0013	0.12	6.0
17–24 in. dia. inc.	1.54	96.0	18.9	400	2,200	790	5.4	0.0014	0.13	6.0
24–40 in. dia., 24 in. sq., 24x30 in. rect	1.54	96.0	18.4	400	1,910	810	4.3	0.0026	0.12	6.0
Blocks										
4x4 in. to 6x6 in.	1.57	97.8	25.0	840	4,100	1,670	9.4	0.0018	0.14	3.0
6x6 in. to 20x20 in.	1.55	96.7	19.2	500	2,140	990	6.1–8.1	0.0016	0.15	4.0
Tubes										
½–4 in. I.D. inc.	1.51	94.2	24.3	885	10,200	2,700	21.0	0.0014	0.15	3.0
5–10 in. I.D. inc.	1.49	93.0	26.2	980	8,140	2,550	17.0	0.0016	0.21	3.0
Brick, standard sizes										
Coal base	1.57	97.8	18.8	970	5,340	1,950	8.9	0.0015	0.14	5.0
Coke base	1.55	96.7	23.1	1,530	8,320	3,070	10.3	0.0016	0.13	3.0
Graphite										
Electric furnace electrodes										
Less than 3 in. dia.	1.55	96.7	30.4	1,910	5,980	3,830	10.0	0.00033	0.04–0.11	94.
3–8 in. dia. inc.	1.56	97.3	30.0	880	3,050	1,750	8.8	0.00036	0.05–0.12	84.
9–12 in. dia. inc.	1.55	96.7	30.4	900	3,420	1,810	8.0	0.00037	0.06–0.12	79.
14–18 in. dia. inc.	1.53	95.3	31.3	750	3,180	1,490	6.7	0.00039	0.08–0.12	70.
Electrolytic electrodes										
2x2 in.–5x5 in. up to 24 sq. in.	1.55	96.7	30.4	1,910	5,980	3,830	10.0	0.00033	0.04–0.11	94.
6x6 in.–10x10 in. inc. 25 to 64.5 sq. in.	1.56	97.3	30.0	880	3,050	1,750	8.8	0.00036	0.05–0.12	84.
12x12 in.–16x16 in. inc. 65 to 144 sq. in.	1.55	96.7	30.4	900	3,420	1,810	8.0	0.00037	0.06–0.12	79.
Over 144 sq. in.	1.53	95.3	31.3	750	3,180	1,490	6.7	0.00039	0.08–0.12	70.
Tubes										
½–4 in. I.D.	1.68	104.7	19.7	780	4,550	2,820	14.0	0.0003	0.12	94.
5–10 in. I.D.	1.67	104.	21.7	870	5,100	2,980	13.0	0.0003	0.12	84.
Brick, standard sizes	1.56	97.3	30.0	880	3,050	1,750	8.8	0.00036	0.05–0.12	84.


Shell
Grout
1/8" cement joint
3/8" cement
3/4" x 3/4" x 1" lg. carbon spacer
Plan of Both Layers of Floor Showing Carbon Spacers
Shell
3 layers asphalt felt or membrane
3/8" cement
Paper dam on all wall joints
3/4" x 3/8" x 1" lg. carbon spacer. 2 required per brick
Section Through Walls Showing Carbon Spacers

Showing two methods of tank lining with carbon brick laid up in poured carbonaceous sulphur cement; the preferred form, at right, takes care of seepage by use of a resistant diaphragm.

Makers of Structural Carbon and Graphite Products

MANUFACTURER (Name and Address)	Products
Acheson Graphite Corp., New York, N. Y.	Graphite electrodes
International Graphite & Electrode Corp., St. Mary's, Pa.	Graphite electrodes
National Carbon Co., Inc., Cleveland, Ohio	Carbon and graphite brick, tile, tower packing, tubes, pipe, special shapes, electrodes
Speer Carbon Co., St. Mary's, Pa.	Carbon and graphite brick, plates, blocks, tubes, cylinders, bushings, shapes
Stackpole Carbon Co., St. Mary's, Pa.	Various carbon and graphite products

Note: Manufacturers of graphite crucibles are listed under "Refractories."

PLASTIC MOLDING MATERIALS

REPRESENTATIVE MAKERS OF MOLDING POWDERS AND OTHER PLASTIC MATERIALS

MATERIAL	MANUFACTURER (Name and Address)	Type
Aladdinite	Aladdinite Co., Newark, N. J.	Casein
Alvar (and others)	Shawinigan Products Corp., New York, N. Y.	Vinyl resin
Ameroid	American Plastics Corp., New York, N. Y.	Casein
Aqualite	National Vulcanized Fibre Co., Wilmington, Del.	Laminated phenolic
Atlastiseal	Atlas Mineral Prods. Co. of Pa., Mertstown, Pa.	Tank lining
Bakelite	*Bakelite Corp., New York, N. Y.	Molding and cast phenolics, urea-form., styrene, cell. ac.
Beckacite (others)	Reichhold Chemicals, Inc., Detroit, Mich.	Lacquer resins
Beetle	*Beetle Prods. Div., American Cyanamid Co., New York, N. Y.	Urea-formaldehyde
Benalite, -loid	Masonite Corp., Laurel, Miss.	Lignin plastics
Catalin	Catalin Corp., New York, N. Y.	Molding and cast phenolics
Celeron	Continental Diamond Fibre Co., Newark, Del.	Molding phenolic
Celluloid	Celluloid Corp., New York, N. Y.	Cellulose nitrate
Crystalite	Rohm & Haas Co., Philadelphia, Pa.	Acrylic resin
Cumar	Barrett Co., New York, N. Y.	Coumarone-indene
Dilecto	Continental Diamond Fibre Co., Newark, Del.	Laminated phenolic
DuPont	*E. I. duPont de Nemours & Co., Wilmington, Del.	Vinyl resin
Duraloy	Detroit Paper Prods. Corp., Detroit, Mich.	Laminated phenolic
Durez	*General Plastics, Inc., No. Tonawanda, N. Y.	Molding phenolic
Durite	Durite Plastics, Inc., Philadelphia, Pa.	Phenolic, phenol-furfural
Duroid	Atlas Mineral Prods. Co. of Pa., Mertstown, Pa.	Bulk and sheet plastics
Ethocel, -foil	Dow Chemical Co., Midland, Mich.	Ethyl cellulose
Formica	Formica Insulation Co., Cincinnati, O.	Laminated phenolic
Harvel	Irvington Varnish & Insulator Co., Irvington, N. J.	Cashew nut derivative
Haveg	Haveg Corp., Newark, Del.	Phenolic-base chemical equipment
Hercules	*Hercules Powder Co., Wilmington, Del.	Ethyl cellulose, cellulose nitrate, acetate
Heresite	*Heresite & Chemical Co., Manitowoc, Wis.	Molding phenolic
Indur	Reilly Tar & Chemical Co., Indianapolis, Ind.	Molding phenolic
Insurok	Richardson Co., Chicago, Ill.	Phenolic and urea-formaldehyde
Lamicoid (and others)	Mica Insulator Co., New York, N. Y.	Laminated phenolic
Lauxite	I. F. Laucks, Inc., Lockport, N. Y.	Plywood resin bond
Lucite	E. I. duPont de Nemours & Co., Plastics Dept., Arlington, N. J.	Methacrylate resin
Lumarith	Celluloid Corp., New York, N. Y.	Cellulose acetate
Makalot	*Makalot Corp., Boston, Mass.	Molding phenolic
Marblette	Marblette Corp., Long Island City, N. Y.	Cast phenolic
Masuron	John W. Masury & Son, Brooklyn, N. Y.	Cellulose acetate
Micarta	Micarta Div., Westinghouse Elec. & Mfg. Co., Trafford, Pa.	Laminated phenolic and urea-formaldehyde
Monsanto	*Plastics Div., Monsanto Chem. Co., Indian Orchard, Mass.	Cast phenolic, cellulose acetate and nitrate, vinyl, arochlor resins
Neville	Neville Co., Neville Is. P. O., Pittsburgh, Pa.	Hydrocarbon and coumarone-indene resins
Nixonite, -oid	Nixon Nitration Works, Nixon, N. J.	Cellulose acetate, nitrate
Ohmoid	Wilmington Fibre Specialty Co., Wilmington, Del.	Laminated phenolic
Panelyte	Panelyte Corp., New York, N. Y.	Laminated phenolic
Phenolite	National Vulc. Fibre Co., Wilmington, Del.	Laminated phenolic
Plaskon	Plaskon Co., Toledo, O.	Urea-formaldehyde
Plastacele	E. I. duPont de Nemours & Co., Plastics Dept., Arlington, N. J.	Cellulose acetate
Plexiglas, -gum	Rohm & Haas Co., Philadelphia, Pa.	Acrylic resins
Pyralin	E. I. duPont de Nemours & Co., Plastics Dept., Arlington, N. J.	Cellulose nitrate
Raurene (and others)	U. S. Industrial Alcohol Co., New York, N. Y.	Varnish resin
Resinox	Resinox Corp., New York, N. Y.	Molding phenolic
Resoglas	Advance Solvents & Chem. Co., New York, N. Y.	Styrene resin
Spauldite	Spaulding Fibre Co., Tonawanda, N. Y.	Laminated phenolic
Styron	Dow Chemical Co., Midland, Mich.	Styrene resin
Synthane	Synthane Corp., Oaks, Pa.	Laminated phenolic
Tego	*Resinous Products & Chem. Co., Phila., Pa.	Phenolic plywood bond
Tenite	Tennessee Eastman Corp., Kingsport, Tenn.	Cellulose acetate
Textolite	*General Electric Co., Plastics Dept., Pittsfield, Mass.	Molding, laminated phenolics
Ucinite	United-Carr Fastener Corp., Cambridge, Mass.	Laminated phenolic
Unyte	Plaskon Co., Toledo, O.	Urea-formaldehyde
Victron	Naugatuck Chemical Co., New York, N. Y.	Styrene resin
Vinylite	*Carbide & Carbon Chem. Corp., New York, N. Y.	Vinyl resin
Vistanex	Advance Solvents & Chem. Co., New York, N. Y.	Hydrocarbon resin

* Also makes varnish and lacquer resins.

RUBBER and LIKE PRODUCTS

Chemical Resistance of Neoprene

Owing to the fact that various compounding ingredients must be mixed with neoprene to develop its desirable properties, it is difficult to state in the absence of actual service tests against which materials any neoprene composition is resistant. Consequently, the manufacturers prefer to work with users in running tests and developing the most appropriate compounds to meet individual problems. Below are listed the general properties of neoprene compositions.

Animal, Vegetable, Petroleum Products. When it is contact with waxes, greases, oils, kerosene, gasoline, and the other higher petroleum fractions, neoprene swells slightly but largely retains its strength, resiliency and rubber-like properties. It is not dissolved, does not become tender and does not slough off small particles. Less highly saturated compounds attack neoprene to a greater extent than the saturated ones.

Oxidizing Chemicals. Neoprene is said to be very resistant to oxidation and to withstand natural and accelerated aging, resisting such chemicals as chlorine which forms a hard, protective film on the surface. It resists oxidizing acids in low concentrations.

Inorganic Chemicals. Such chemicals have little effect on neoprene although special compositions, proved under actual service conditions, are often advisable.

Organic Chemicals. Neoprene resists the attack of most organic compounds, the more highly saturated compounds having less effect than the less saturated.

Neoprene is not recommended for use with lacquer thinners, the chlorinated organic compounds, creosote, or concentrated nitric and sulphuric acids.

Properties of Thiokol Synthetic Rubber

The manufacturers of Thiokol synthetic rubber state that this material has physical characteristics similar to natural rubber and is processed in much the same manner. However, unlike rubber, it is practically unaffected by petroleum hydrocarbons and most commercial solvents. It is unaffected by alcohols, ketones and esters. While showing some swell in the aromatic hydrocarbons it still retains good physical characteristics. It is unaffected by some chlorinated solvents such as carbon tetrachloride, but attacked by others, like ethylene dichloride.

Thiokol is said not to be affected by sunlight, air, ozone, and ultra-violet light.

It can be compounded to give various hardnesses and characteristics suitable for each particular application. While not possessing original tensile strength as great as natural rubber, it is stated far to exceed natural rubber in both strength and abrasion resistance when in contact with gasoline and oils. Since it has extremely low permeability, there is practically no diffusion loss through Thiokol when conducting volatile solvents.

This material can be used at temperatures ranging from 200 deg. F. to —40 deg. F.

SOLVENT RESISTANCE OF THIOKOL SYNTHETIC RUBBER

(Immersion tests at room temperature for one year. Percentage swell determined from increase in length of 1/4 x 1/16 x 4-in. test strips.)

Solvent	Per Cent Swell	Condition	Solvent	Per Cent Swell	Condition
Motor gasoline	1.0	OK	Drip oil	13.8	OK
80/20 gasoline/benzol (by vol.)	3.0	OK	Linseed oil (raw)	1.3	Surface hardened
50/50 gasoline/benzol (by vol.)	6.3	OK	Cottonseed oil	0.0	OK
Benzol	25.0	Firm	Acetone	2.5	OK
Kerosene	0.8	OK	Methyl alcohol	1.3	Surface slightly affected
SAE No. 30 motor oil	0.5	OK	Carbon tetrachloride	8.8	OK
No. 4 fuel oil	3.5	OK	Ethylene dichloride	Destroyed	

PHYSICAL PROPERTIES OF RUBBER AND RUBBER-LIKE MATERIALS

MATERIAL	Form	Specific Gravity	Compressive Str., Lb. per sq. in.	Tensile Strength, Lb. per sq. in.	Transverse Strength, Lb. per sq. in.	Hardness, Shore Durometer	Max. Temp. for Use, °F.	Effect of Heat	Coef. Lin. Expan., per °F. (Multiply by 10^{-5})	Coef. Therm. Conduct., B.t.u. per sq. ft., in., hr., °F.	Abrasion Resistance	Tear Resistance, Lb. per sq. in.	Dielectric Str., Volts per mm.	Effect of Sunlight	Effect of Aging	Machining Qualities
Koroseal	Hard	1.3–1.4	.....	2,000–9,000	.....	80–100	212	Softens	.....	.....	Good	....	30,000–50,000	None	None	Good
Koroseal	Soft	1.2–1.3	.....	500–2,500	.....	30–80	190	Softens	.....	.....	Good	....	15,000–30,000	None	None	Can be ground
Neoprene	.....	1.27–3.00	.....	200–4,000	.....	15–95	300	Stiffens slightly	.....	1.45	Equal to rubber	3–30	.....	Nil	Stiffens slightly	Can be ground
Plioform	Plastic	1.06	8,500–11,000	4,000–5,000	7,000–9,000	.....	160–248	Softens	.....	.....	.....	....	.....	Nil	None	
Rubber* (typical)	Hard	1.17–1.18[1]	6,000–11,000	4,000–11,000	15–30[2]	70–100[3]	220	Softens 180–212 °F.	7.7	1.10–1.28	Good	....	1,000–3,800[6]	Discolors	None	Excellent
Rubber* (typical)	Soft	0.928–1.17	.....	1,000–6,000	.....	30–80[3]	150–180	[4]	6.7	0.84–0.99	Excellent	[5]	1,000–1,400[6]	Deteriorates[7]	Highly resistant	Can be ground

* Rubber data supplied through courtesy of H. H. Harkins and O. S. True, U. S. Rubber Co.

[1] Value for true ebonite. Specific gravity of commercial compounds depends on compounding materials.

[2] Falling weight method, ft. lb. per sq. in.; 3 x 3/16 x 1/2-in. specimen, supports 2 in. apart.

[3] Duro A.

[4] Softens and deteriorates at high temperatures.

[5] Samples 0.1 in. thick cut and two sides of cut pulled apart by machine at 1 in. per minute. Resistance 1–15 lb.

[6] Volts per mil (0.001 in.).

[7] Unless specially compounded.

REPRESENTATIVE MAKERS OF INDUSTRIAL RUBBER PRODUCTS AND RUBBER-LIKE MATERIALS

MANUFACTURER (Name and Address)	Products	MANUFACTURER (Name and Address)	Products
American Hard Rubber Co., New York, N. Y.	Hard and soft rubber linings, pipe, fittings, shapes, pails, pumps, rubber paint, etc.	Jenkins Bros. Rubber Div., Bridgeport, Conn.	Mechanical rubber goods, packings
Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor and transmission belts, hose, mechanical rubber goods	The Osborn Mfg. Co., Johns Conveyor Div., Cleveland, Ohio	Johns rubber "moving pipe-line" conveyors
Collord, Inc., Detroit, Mich.	Seamless rubber linings	Maurice A. Knight, Akron, Ohio	Rubber drums, Pyroflex rubber-like plastic lining
Crane Packing Co., Chicago, Ill.	Rubber packings	Linear Packing & Rubber Co., Philadelphia, Pa.	Rubber packings
Custodis Construction Co., New York, N. Y.	Custoplast plasticized latex rubber tank linings	Luzerne Rubber Co., Trenton, N. J.	Hard rubber pipe, fittings, valves, shapes, tanks, rayon apparatus and other equipment
Dayton Rubber Mfg. Co., Dayton, Ohio	Oilproof rubber belts	Manhattan Rubber Mfg. Div., Passaic, N. J.	Transmission and conveyor belting, blocks, hose, piping, rolls, brake lining, bearings
E. I. duPont de Nemours & Co., Neoprene Div., Wilmington, Del	Neoprene polymerized chloroprene synthetic rubber	Miller Rubber Co., Akron, Ohio	Hose, molded products, linings and coverings
Garlock Packing Co., Palmyra, N. Y.	Rubber packings	Resistoflex Corp., New York, N. Y.	Rubber-like oil-resisting resin, various shapes
Gates Rubber Co., Denver, Colo.	Transmission and conveyor belting	Self-Vulcanising Rubber Co., Chicago, Ill.	Liquid and plastic rubber self-vulcanising coatings and lining materials
L. H. Gilmer Co., Tacony, Philadelphia, Pa.	Transmission belting	Jos. Stokes Rubber Co., Trenton, N. J.	Molded hard rubber products of all kinds
B. F. Goodrich Co., Akron, Ohio	Acid- and abrasion-resistant linings, hose, conveyor and transmission belting, packings, hard-rubber pipe and molded goods, rubber paints, Koroseal plastic, Anode process	Thermoid Rubber Co., Trenton, N. J.	Hose, belting, packing, mechanical rubber goods
		Thiokol Corp., Yardville, N. J.	Thiokol olefine polysulphide synthetic rubber—crude sheet and molding powder
Goodyear Tire & Rubber Co., Akron, Ohio	Hose, conveyor and transmission belting, packings, linings, mechanical rubber goods, Plioform modified rubber plastic	U. S. Rubber Co., New York, N. Y.	Rubber-lined pipe, hard, semi-hard and soft linings, abrasion-resistant linings, hard rubber pipe, acid hose, packings, mechanical rubber goods
Hercules Powder Co., Wilmington, Del.	Tornesit chlorinated rubber for paints		
Hewett Rubber Corp., Buffalo, N. Y.	Hose, transmission and conveyor belting, packings	Vulcanized Rubber Co., New York, N. Y.	Hard and semi-hard rubber molded products

WOOD for CHEMICAL EQUIPMENT

PHYSICAL PROPERTIES OF WOODS

	Cypress	Douglas Fir (Coast.)	L. L. Y. Pine	Redwood	Sugar Maple	White Oak
Lb. per cu. ft. (12% moisture)	32	34	41	28	44	47
Tensile str.,* lb. per sq. in (12% moisture)	7,200	8,100	9,300	6,900	9,500	7,900
Compressive str.,* lb. per sq. in (12% moisture)	4,740	6,450	6,150	4,560	5,390	4,350
Thermal cond., B.t.u. per sq. ft., hr., °F., in.	0.83	0.77	0.96	0.76	1.16	1.22
Hardness	Med.	Med.	Hard	Mod. hard	Med.	Hard

* At proportional limit, in statle bending, and compression parallel to grain, respectively.

CONDITION OF WOODS AFTER 31 DAYS IMMERSION IN COLD SOLUTIONS*

(Examined after 7 days drying)

	Fir	Oak	Oregon Pine	Yellow Pine	Spruce	Redwood	Maple	Cypress
Hydrochloric Acid, 5%	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
Hydrochloric Acid, 10%	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
Hydrochloric Acid, 50%	SS,SB,SWF	SS,WF	S,WF	S,WF	S,WF	S,WF	S,WF	S,WF
Sulphuric Acid, 1%	NAC	NAC	NAC	SS	SS	NAC	NAC	SS,SB
Sulphuric Acid, 5%	SS	SS	SS	SS	SS,SB	SS,SB	NAC	SS,SB
Sulphuric Acid, 10%	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD
Sulphuric Acid, 25%	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD
Caustic Soda, 5%	S,NAC	MSh,SWp	SS	SS,FSD	SSp,FSD	SSp,FSD	MSh	SSp,FSD
Caustic Soda, 10%	S,FSD	MSh,WF,Horny	SS	SS,SB,FSD	SS,SB,FSD	SS,SB,FSD	MSh	S,SB,FSD
Alum, 13%	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium Carbonate, 10%	SB,GC	NAC	GC	SB,GC	SB,GC	SB,GC	GC	SB,GC
Calcium Chloride, 25%	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Common Salt, 25%	NAC	NAC	NAC	SS,GC	SS,GC	SB,GC	NAC	NAC
Water	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium Sulphide	SS,SB	Msh,WF	SB	SB	SB	SB	MSh,FSD	FSD

CONDITION OF WOODS AFTER 8 HOURS BOILING IN SOLUTIONS*

(Examined after 7 days drying)

	Fir	Oak	Oregon Pine	Yellow Pine	Spruce	Redwood	Maple	Cypress
Hydrochloric Acid, 10%	SB,S	FSD	FSD	FSD	FSD	FSD	FSD	FSD
Hydrochloric Acid, 50%	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG
Sulphuric Acid, 4%	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC
Sulphuric Acid, 5%	SS,GC	SB,GC	SB,GC	SB,GC	SB,FSD	SB,GC	SB,GC	SB,FSD
Sulphuric Acid, 10%	SS,GC	B,FD,Wpd,NG	Sp,FD,NG	B,Sp,FD,NG	B,Sp,FD,NG	SB,FSD	SB,FSD	B,FD
Caustic Soda, 5%	SS	MSh	S	GC	S,GC	S,GC	Sh	SSp
Alum, 13%	SB,GC	NAC	NAC	SB,GC	SB,GC	SB,GC	NAC	SB,GC
Sodium Carbonate, 10%	SB,GC	GC	GC	GC	GC	GC	GC	SB,GC
Calcium Chloride, 25%	SB,GC	SB,SS,GC	NAC	SB,GC	SB,GC	NAC	NAC	SB,GC
Common Salt, 25%	NAC	NAC	NAC	SB,GC	NAC	SB,GC	NAC	NAC
Water	NAC	NAC	NAC	SB,GC	NAC	NAC	NAC	NAC

*The two charts describing the condition of eight varieties of woods used for tanks and other chemical-resistant uses are based on a report of James K. Stewart, consulting chemist, to the Mountain Copper Co., Martinez, Calif. Tests were conducted on samples 1 x 4 x ¼ in. in size, seasoned and chosen so as to be as nearly as possible in the same physical condition as the woods would be when used for equipment construction. Results of the tests are described by terms explained in the following key:

Abbreviation Key

B — Brittle
Ch — Charred
FD — Fiber Disintegrated
FSD — Fiber Slightly Disintegrated
GC — Good Condition
MSh — Much Shrunk
NAC — No Apparent Change
NG — No Good
S — Softer
SB — Slightly Brittle
Sh — Shrunk
Sp — Spongy
SS — Slightly Softer
SSp — Slightly Spongy
SWF — Slightly Weakened Fiber
SWp — Slightly Warped
WF — Weakened Fiber
Wpd — Warped

Representative Makers of Wood Tanks and Pipe for Chemical Applications

Acme Tank Co., New York, N. Y.
Alert Pipe & Supply Co., Bay City, Mich.
Atlantic Tank Corp., North Bergen, N. J.
Axtell Co., Fort Worth, Tex.
Baltimore Cooperage Tank & Tower Co., Baltimore, Md.
Black, Sivalls & Bryson, Inc., Oklahoma City, Okla.
W. E. Caldwell Co., Louisville, Ky.
Challenge Co., Batavia, Ill.
A. J. Corcoran, Inc., Jersey City, N. J.
Cypress Tank Co., Shreveport, La.
Dempster Mill Mfg. Co., Beatrice, Neb.
Drummond Mfg. Co., Louisville, Ky.
G. Elias & Bro., Buffalo, N. Y.
Engle Tank Co., Chicago, Ill.
Federal Pipe & Tank Co., Seattle
Fleming Tank Co., Pittsburgh, Pa.
Fibre Conduit Co., Orangeburg, N. Y.
General Tank Corp., Kearny, N. J.
Amos H. Hall & Sons, Philadelphia
Hauser-Stander Tank Co., Cincinnati, Ohio
Hammond & Little River Redwood Co., Samoa, Calif.
Hammond Lumber Co., San Francisco, Calif.
Henderson Bros. Co., Waterbury, Conn.
R. R. Howell & Co., Minneapolis, Minn.
Johnson & Carlson, Chicago, Ill.
Kalamazoo Tank & Silo Co., Kalamazoo, Mich.
Michigan Pipe Co., Bay City, Mich. (Pipe)
National Tank Co., Tulsa, Okla.
National Tank & Pipe Co., Portland, Ore.
New England Tank & Tower Co., Everett, Mass.
Pacific Cooperage Co., Portland, Ore.
Pacific Wood Tank Corp., San Francisco, Calif.
Pacific Tank & Pipe Co., Oakland, Calif.
Redwood Mfrs. Co., San Francisco
Wendnagel Co., Chicago, Ill.
G. Woolford Wood Tank Co., Darby, Pa.
A. Wyckoff & Son Co., Elmira, N. Y. (Pipe)
Wyckoff Pipe & Creosoting Co., New York, N. Y.

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